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JETRO

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VOL.25 NO. 9

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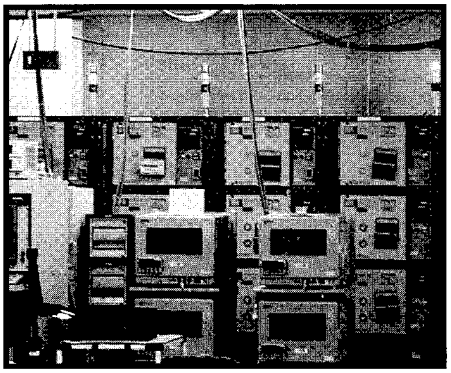

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Cover Photo : Advanced Synthetic Crystal Units & Oscillator Manufacturing Plant - Hobara Plant of Tokyo Communication Equipment Co.-(Story on Pages 2-4)

CONTENTS

KEIRIN 本印刷物は，日本自転車振興会から，競輪収益の一部である機械工業振興資金の援助を受けて作成したものである。

NEW TECHNOLOGY & PRODUCTS 30

INNOVATIVE PRODUCTION NOW

This section describes a specialized section or whole process of a representative factory which excels in specific aspects of production.

Advanced Synthetic Crystal Units & Oscillator Manufacturing Plant

- Hobara Plant of Toyo Communication Equipment Co. -

1. Introduction

Synthetic crystal devices are essential for modern telecommunications, electronics and laser devices including cellular and PHS phones, game machines, electronic watches, telecommunications devices and components, car electronics, electronic devices and parts, information processing equipment, personal computers and even to digital & computing networks and multimedia devices.

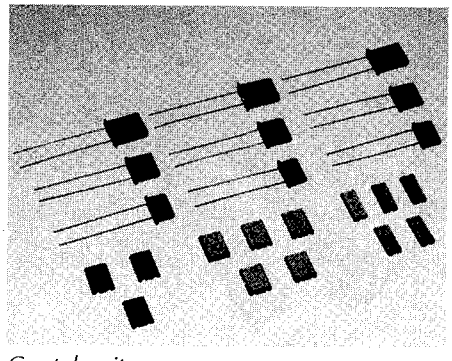
Presently, Japanese manufacturers hold the leading position in the world market with a share of about 70% for synthetic crystal devices.

This issue introduces the Hobara Plant of Toyo Communication Equipment Co. (TOYOCOM), which is one of the Japan's most modern synthetic crystal units and devices plants.

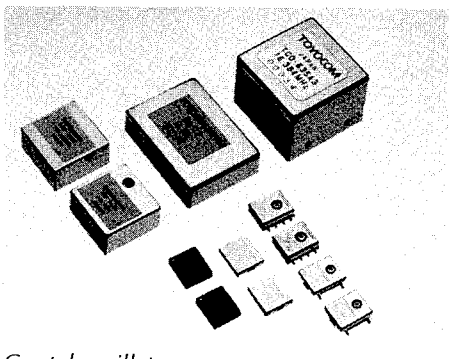
TOYOCOM first began to producing synthetic quartz crystals available for working in extreme high temperature and pressure environments in 1956 and established the production technology. The company then started mass production in 1960, and now it is operating three plants in Hobara, Miyazaki and Odaka Plants domestically and two plants in Indonesia and Malaysia for production of synthetic crystal units and devices.

The Hobara Plant is the key plant for production of synthetic crystal devices in the company.

View of the Hobara Plant



Crystal units



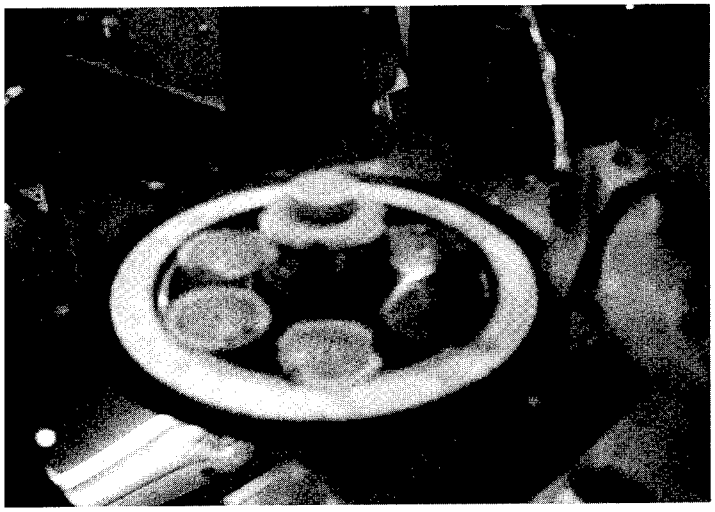
Crystal oscillators

2. Outline of the Plant

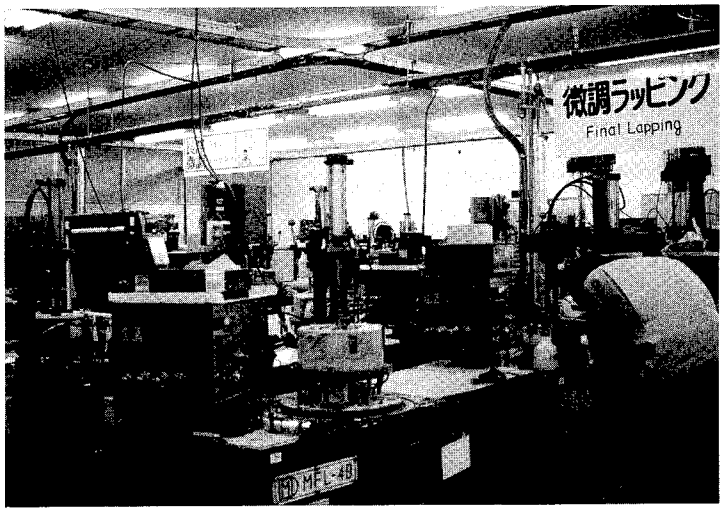
(1) History

Hobara Plant is located at the Hobara Industrial Complex in Hobara-machi, Date-gun, Fukushima Pref. It is about 2 hours by JR Tohoku Shinkansen from Tokyo to Fukushima Station and 30 minutes from Fukushima Station to the plant by taxi.

The plant was constructed in 1972 as the Fukushima Toyo Communication Equipment Co., started production of synthetic crystal quartz and crystal products in May 1973, and established integrated production line from synthetic crystallization process to synthetic crystal devices in 1975.



Crystal blank lapping process



Final lapping process

The production of HCM was started in June 1975, and the mass production of synthetic crystal units for watches in Apr. 1976. In 1989, a new automatic production plant with clean room facilities was completed. Production of surface mounted devices (SMD) was started in same year. The company was merged by TOYOCOM as its Hobara Plant in 1994, and certified ISO9001 in same year. The Hobara plant is now hoping to receive ISO14001 certification in the next year.

(2) Plant Site and Products

Hobara Plant has a land area of 287,000 m^2 and 129,291 m^2 for factory and office buildings & others. Employees are 582 in total including staffs of headquarters divisions at the plant. Production facilities are composed of No.1 factory for production of synthetic crystal wafers, and No.2 factory equipped with clean rooms and the most modern production equipment for production of synthetic crystal units, crystal oscillators, etc. including SMD production equipment.

Production processes extend from the production of synthetic crystal wafers to synthetic crystal units, oscillators, etc. Material crystal blanks based on synthetic & lumbered quartz crystals are supplied from its Miyazaki Plant, in which the production of these quartz and crystal blanks are integrated.

(3) Plant Operation and Production Capacity

The Hobara Plant is operating under the 24-hour and around the year systems with 2 or 3 shifts setup, except the 1 shutdown day per month for regular maintenance of production facilities.

All production is based on client orders, and the product specifications are slightly different for each client, so it can be said that the production is the multi-type/ small-lot production system.

Monthly production capacity of the plant is over 8 million units of synthetic crystal wafers, 1.5 million units of crystal oscillators, 5 million units of crystal units, 200 thousand units of current sensors, and 300 thousand units of laser diode oscillators.

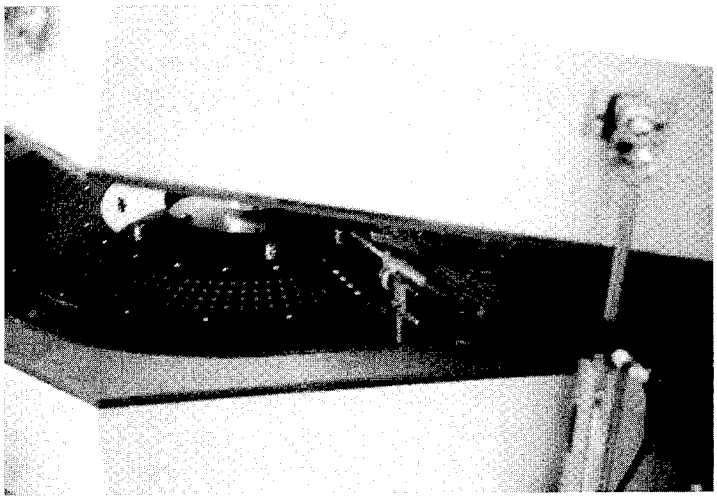
3. Production Process and Technological Highlights

(1) No.1 Factory

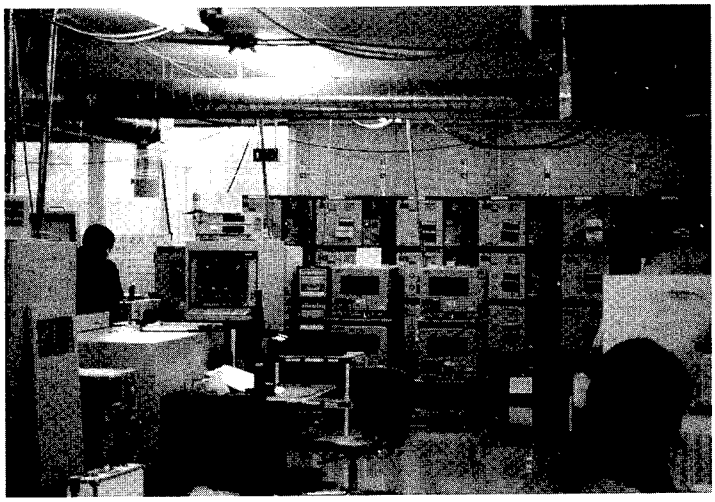
The No.1 factory is usually producing two types of synthetic crystal wafers - round and rectangular types. These are produced by the following processes.

Rectangular etching process: Crystal blanks - lapping-classification by frequencies - arrangement - gluing - cutting - outer-shape lapping- detaching- etching, classification by frequencies - outer (visual) inspection

Round wafer process: Crystal blanks - arrangement-lamination and gluing - round shape processing - detaching- lapping - classification by frequencies - etch-



Temperature testing chamber



Aging test facilities

Automated crystal unit production lines in clean room

Circular assembly lines for crystal oscillators

ing & polishing - classification by frequencies - outer (visual) inspection.

In these processes, various advanced equipment and expertise are applied for the etching, polishing, grinding, detaching, etc.

(2) No.2 Factory

The No.2 factory is a two story building with the 2nd floor provided with modern facilities including automated machines, clean rooms, and other equipment for production of crystal units, and 1st floor with unique mass production lines - circular assembly lines - for production of crystal oscillators.

SMD unit production lines are also established based on advanced automation systems and unique operation know-how.

(3) Quality Inspection

Quality inspection of these products are performed on product characteristics, shapes, performances, durability, etc. in each process both automatically and manually to secure the accuracy and temperature durability.

Final product quality assurance is intensively performed by the quality assurance divisions before shipment.

4. Promotion of Cost Effective Management Measures

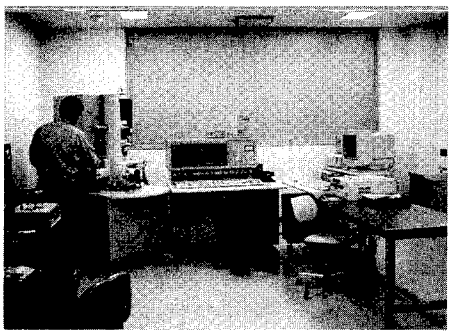
Production yields for the production of crystal wafers to final products is about 80% on average at present. To attain the high-performance plant management, Hobara Plant has now promoting aggressive methods called the "HOPS" As a result of this scheme, for example, the cost was reduced to 40% in the first half of 1996 from the 100% bench mark in Jan., 1995, and is targeted to fall to 30% in the first half of 1997. For production efficiency, the bench mark of 100% in Jan. 1995 was improved to 300% in the first half of 1996, and will attain 350% in the first half of 1997. Regarding the production lead time, the bench mark of 24 days in Jan. 1995 was reduced to 5 days in the first half of 1996, and targeted to be 2 days in the first half of 1997. The trends in the number of production units per 1 m^2 was also improved from the bench mark of 240 units in Jan. 1995 to 900 units in the first half of 1996, and will attain 1000 units in the first half of 1997.

The configuration of the assembly line of the crystal oscillators was changed from the straight lines to the circular lines which created spaces applicable for other purposes. At the straight assembly lines, there were no margined spaces. The first improvements of line configuration created about 20 m^2 of margined spaces due to reorganization of process flows and narrowing the intervals of the lines, 35 m^2 at the second-phase with boosting multi-operating capability of workers and improvement of balancing the operation loads of workers, 50 m^2 at third-phase with improvement of production efficiency and balancing the operation loads of workers, 60 m^2 at the fourth-phase with improvement of operation flow and production efficiency, and 50 m^2 at fifth-phase with the improvement of efficiency by introduction of automation systems.

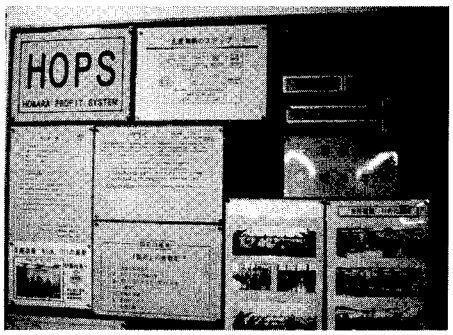
Thus, this plant has attained drastically higher production efficiency.

5. Post Script

The Hobara Plant is maintained with clean conditions and high production efficiency by promoting various improvement measures and development and establishing the technical know-how, and assures higher product performances and quality. At present, these improvement measures at the plant are continuing to cope with severe client requirements both for cost reduction and quality in domestic and foreign markets.



Electron microscope for quality assurance



Information for cost effective plant management

Hobara Plant

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NATIONAL R&D PROJECTS

This section describes various R&D projects being carried out in Japan on a national scale.

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World's Highest 70,000-kW Output with Superconducting Generator

As a link of the New Sunshine Program of the Agency of Industrial Science and Technology, Ministry of International Trade and Industry, the Superconducting Generator-Related Equipment and Materials Technical Research Association has been developing applied superconducting power technologies under a 11-year project from FY 1988. On June 11 this year, a 70,000-kW class superconducting power generator demonstrative test facility was completed inside the Test Center at the Osaka Power Station of Kansai Electric Power Co., Inc. and began various tests.

This demonstration test is to verify the operational performance and reliability of the superconducting generator in linkage with its chiller system. The generator is the world's largest class facility and the first of its type to enter actual power generation and will enter the longest period of operation. Previously the longest period of continuous operation had been about 100 hrs on a laboratory scale (90-kW class), but this demonstration test is scheduled for continuous operation for over 1,000 hrs. A group of experts made an inspection tour of the power generation facility when the International Conference on Large Electric Systems (CIGRE) was held in Japan last month.

Outline

1. The objectives of the 70,000-kW class model superconducting generator are to establish and verify the basic technologies indispensable for designing and manufacturing a 200,000-kW class pilot generator that is scheduled for development commercializing a futuristic superconducting power generator. Presently under development are three types of model rotors (a slow-response type-A rotor, a slow-response type-B rotor and an ultrafast response type rotor) with the excitation control system (response system) and ancillary field winding (superconductor), the damper structure and the heat contraction mechanism having different specifications. A stator is also under development to be employed in conjunction with these rotors. This time, the slow-response type-A rotor was used and the world's highest output level of 70,000 kW attained.

2. The R&D activities conducted previously have provided many remarkable results. For example, in the sector of superconductors which are used as the field windings of generators, a conductor of the world's highest level (electric conductance of about 20 kA with field of 5 T and at a liquefied helium temperature of -269 °C) has been developed, and for the development of chiller systems, a system operable continuously for 10,000 hrs has been designed for use by a commercial superconducting generator.

3. The 70,000-kW class model generator demonstration tests will be conducted by the M-G method (loading-back method) that enables load tests and severe tests to be performed without exerting adverse influences to the power system. The contents of these tests are based on the test items of existing generators and include the long-term operational test that is conceived to be necessary for superconducting generators in the stage of their commercialization, also three-phase sudden shortcircuiting tests which provide the severe conditions which may occur in the process of continuous operation of power systems. Based on the results of these tests, the objectives are to assess the basic performances and characteristics of superconducting generators, to establish technologies necessary for designing and fabricating pilot generators, and to verify the operational reliabilities of superconducting generators.

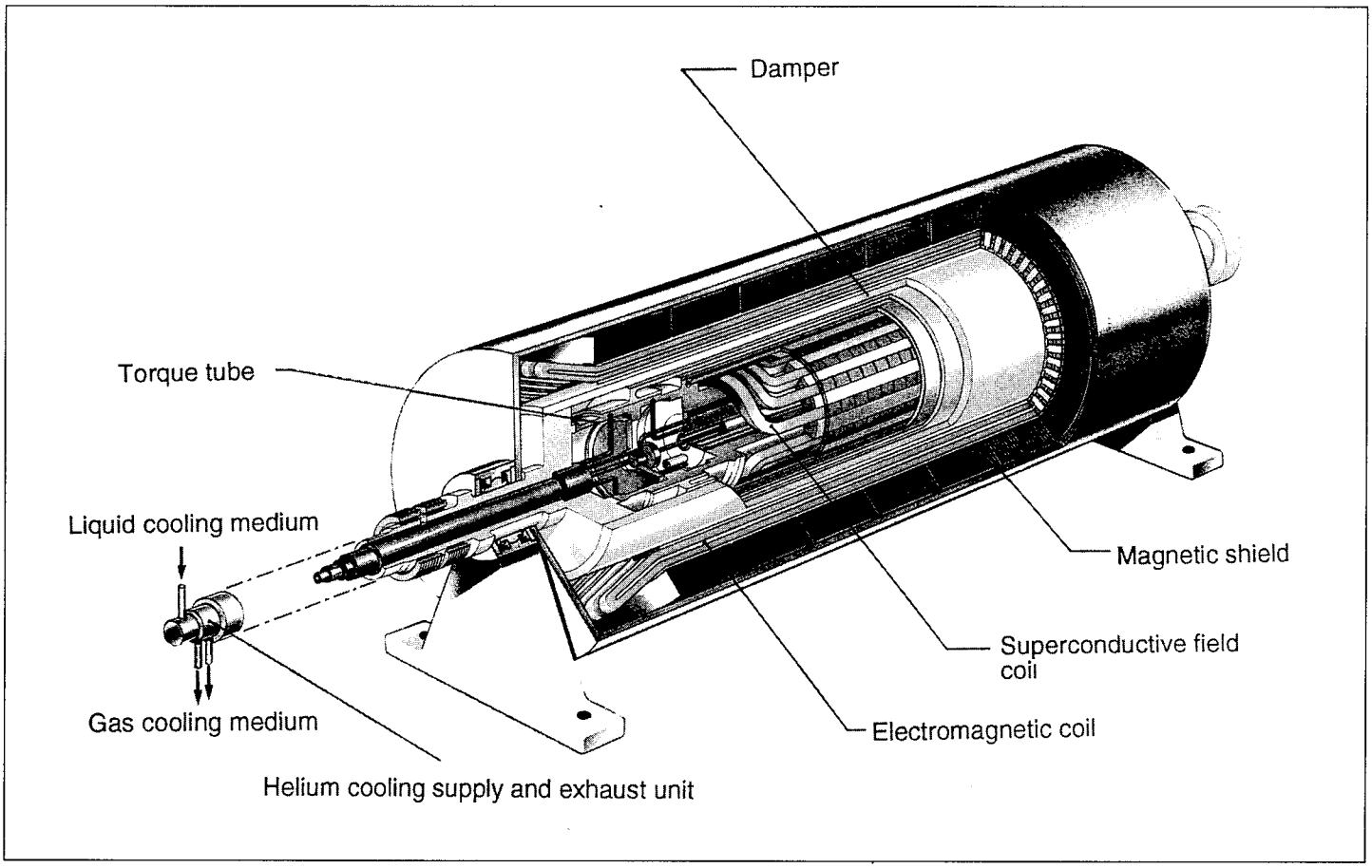
4. The results of these demonstration tests as well as the progress achieved in basic technologies in connection with superconducting wires will be fed back to the designing and fabrication of pilot generators for commercializing superconducting generators, while striving for further performance improvement and to verify the operational reliabilities and operabilities of these generators in actual power systems, as verification had not been possible with model generators, with the schedule of engaging in coordinated system commercialization and commercializing a practical system by about the year 2010 and immediately beyond.

For Reference

Advantages of the Superconducting Generator

1. Efficiency improvement: The power generation efficiency will be improved by about 1%.
   *Specifically, the introduction of the superconducting generator into all thermal and nuclear power generation stations could supply electricity to about 2,300,000 more households.
   *Alternatively, fuel oil will be conserved by about 1,100,000 kiloliters (550,000 drum cans) annually.
   *In thermal power generation of 1 million kW, reductions of 8,400 t/year of CO2 generation in coal-fired thermal power stations, and 4,400 t/yr of CO2 in LNG-fired thermal power stations can be achieved.
2. Compactness, lightness and larger capacity: The sizes and weights of generators will be reduced to about one-half.
3. Improvement of network stability: The power transmittable with power transmission lines can be increased by 1.2-1.5 times.
4. Expansion of limit of fabricating large-capacity systems and equipment: Large-capacity systems and equipment could be fabricated with capacities of about 2 times the present maximums.

	Present 1 Million kW Class Generator	Comparable Superconducting Generator
Overall length	13 m	8 m
Total weight	800 t	400 t



Outline of Superconductive Generator

GENERIC TECHNOLOGY REVIEW

This section describes various basic research and development activities in Japan to inform the world about generic R&D efforts here.

Research on Functions and Structures of Cold-Adaptive Proteins

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Research on Functions and Structures of Cold-Adaptive Proteins

Hokkaido National Industrial Research Institute

Objectives of Research

Living organisms exposed to cold environments reveal functions indispensable for viability in cold environments. The proteins synthesized by living organisms in cold environments generate in their cells consist of anti freeze proteins which inhibit the freezing of body fluids as well as enzymes with high activities even in cold environments. This function is closely related to the chemical structures of their produced proteins although the correlation has not yet been clarified.

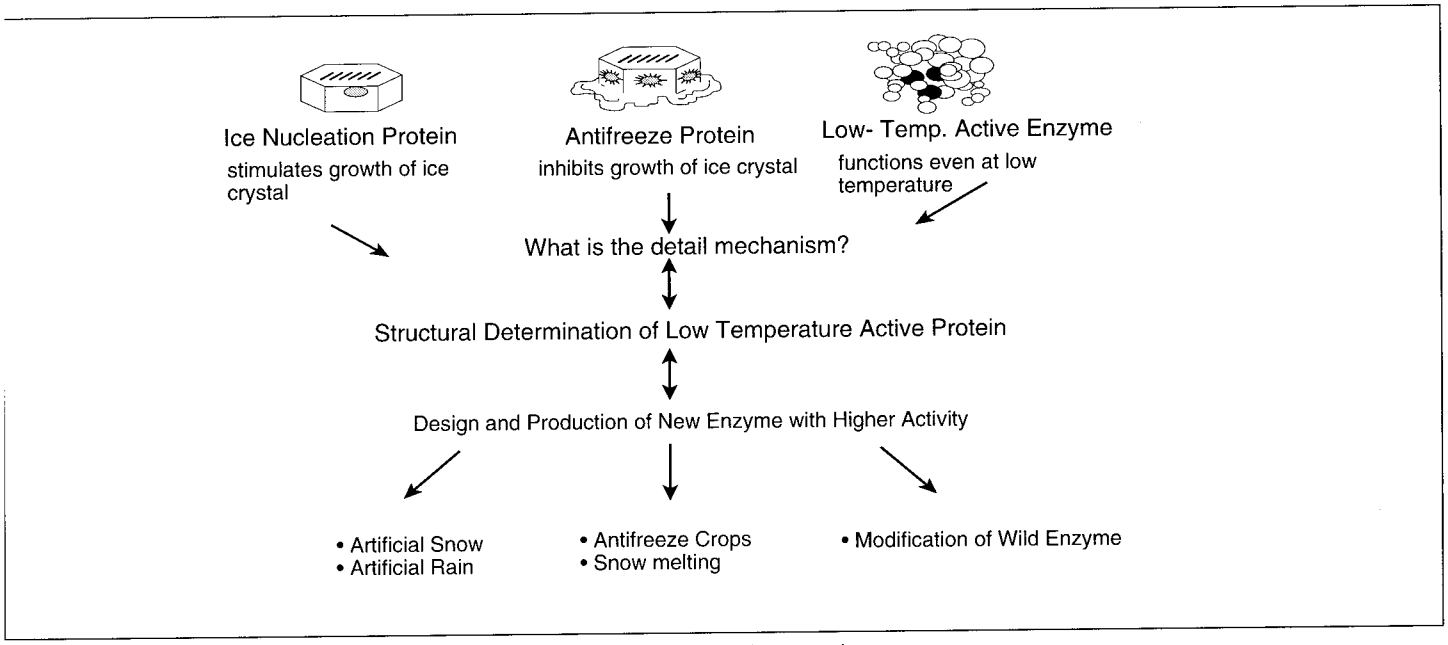
Research on proteins displaying cold adaptation is being advanced in Japan by Hokkaido University's Low Temperature Science Laboratory, Tohoku University and Kyoto University, while in other countries, research is being advanced by organizations in Norway, Canada and the United States. However, not much progress has been achieved throughout the world especially in the biochemical analysis on a molecular level. In this research project, analysis will be advanced on the molecular level to elucidate the functions and structures of proteins of these living things which adapt in the cold environment, with the objective of using the results in industrial applications.

Overall Plan

Cold-adaptive proteins are new dimer antifreeze proteins which inhibit body fluids freezing, enzymes with high activities even in low-temperature, and proteins relating to cell division. Research will elucidate the mechanisms of cold-adaptation in living organisms. The correlation between protein structures and gene structures with respect to biochemical functions will be elucidated on the structural biochemical molecular level.

Anticipated Repercussion Effects

The results of this research project are anticipated to have repercussion effects, or to provide vital basic knowledge to elucidate how living organisms adapt to cold environments, and the antifreeze proteins are expected to promote the development of innovative freezing technologies and to enable incorporation of the antifreeze property in plants. Meanwhile, protein-degradating enzymes with high activities in lower temperature, for example, are expected to enable the development of enzymes for addition to cold water detergents, and thereby to promote industrial technologies considerably.



Studies on the structure-function relationship of the low-temperature active protein

97-12-100-01

Technology to Manufacture Superconducting Coils

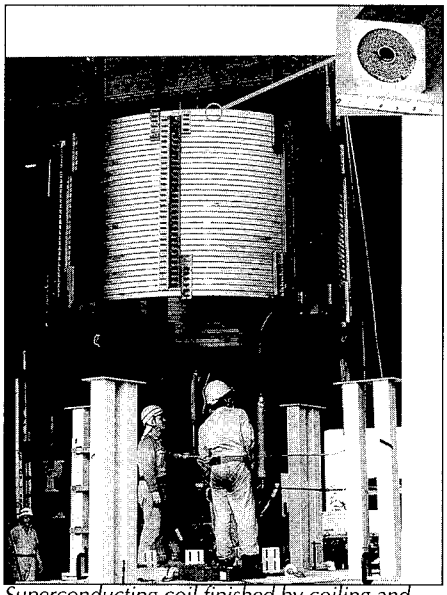
The Japan Atomic Energy Research Institute (JAERI) has succeeded in establishing precision coil manufacturing technology to produce large superconducting coils for the confinement of plasma used in nuclear fusion reactors, and a heat treatment technology that determines the coil superconducting performance.

Current-passing tests of the heat-treated superconductivity confirmation samples showed that the superconducting critical current density (maximum current passable through the superconducting wire) was 550 A/mm^2 in a magnetic field of 12 T, indicating the attainment of a state of superconductivity, or a resistance value of zero. JAERI observes that a breakthrough has been achieved in the technological barrier to manufacture coils for use in the international thermonuclear experimental reactor (ITER).

The superconducting coil was fabricated successfully this time in Japan through joint international division of tasks by assembling the stranded wires supplied by Japan, the conductor metal pipe supplied by the United States, and an assembly consisting of superconducting stranded wires and pipe carried out by Europe.

Normally, raising the critical current density increases the conductor radiation heat generation due to pulsed, but an advanced wire was developed through research that improves the current density and suppresses the radiation heat. With this wire, the density of tin in the copper-tin alloy for implanting the superconducting filaments was increased, and the filament dimensions and alignment were optimized, by which the advanced wire displayed a high critical current density of over 550 A/mm^2 and the generation was decreased to one-fifth compared with before.

The coil part made of this wire can withstand an intense electromagnetic force, so a large-current conductor with a hardness



Superconducting coil finished by coiling and heat treatment

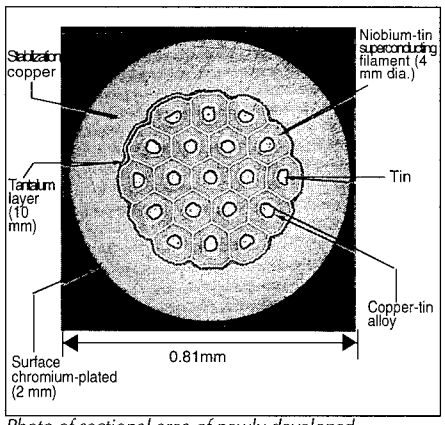
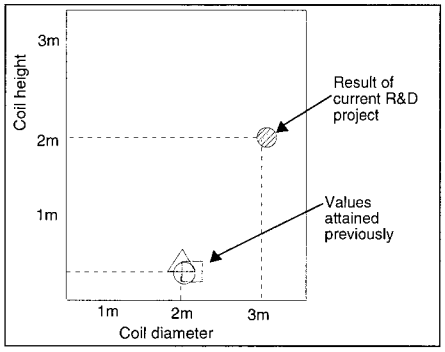


Photo of sectional area of newly developed superconducting wire



Performance of heat-treated superconducting coil

that is seven times greater was used, and a conductor 1,340 m long that is highly resistant to bending was used and finished into a roundness accuracy of ±4 mm with respect to a diameter of 2,950 mm. In parallel, a winding machine equipped with a conductor bending roller was developed to enable the coil to be fabricated accurately.

Heat treatment was accomplished in a large heat treatment furnace for 240 hrs at 650 ± 5 °C, in which case the oxygen density has to be controlled to below a ten millionth part. The furnace environment was maintained in vacuum state for 65 hrs at 450 °C, the generated oxygen was exhausted and high-purity argon gas passed through the furnace, by which the oxygen density was suppressed to 1-2 hundred millionth part.

By the development of these basic technologies, it became possible to clear the technological obstacles successfully, and the attainment of target numerical values was confirmed through tests with samples.

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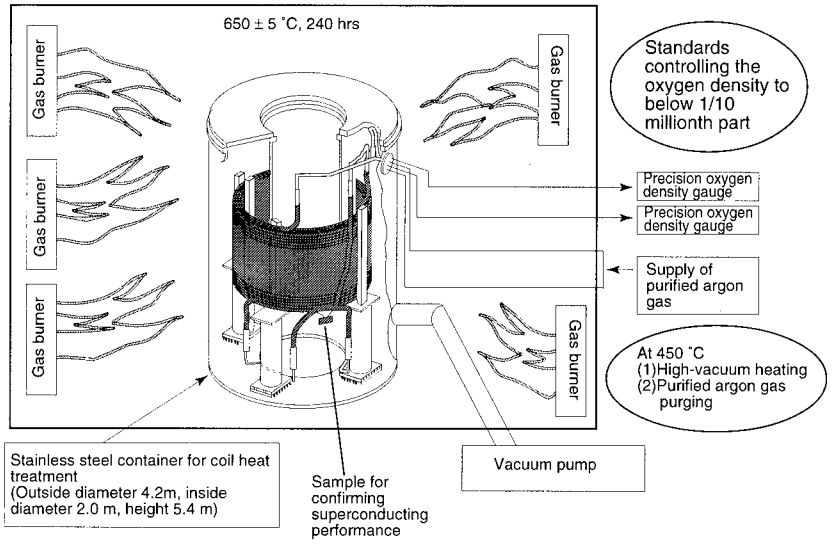
Heat treatment furnace used in current R&D project (W10 × D11× H6m)



Special Features

chnical Problems of Next-Generation Supersonic ransport (SST) and Japan's Policy to Cope with These Problems

Shoji Maekawa, Deputy
Futuristic Aircraft Planning Office,
Foundation Japan Aircraft Development Corporation

I. Introduction

Over 20 years have elapsed since Concorde made her maiden light, and in Western countries, research is presently in progress o develop the next-generation supersonic transport (SST). In the Jnited States, Boeing and McDonnell Douglas are assuming the eadership of the High-Speed Research Program (HSRP) that was mplemented in 1990 based on a contract with NASA. Meanwhile, n Europe, Aerospatiale, British Aerospace and DASA are advanc- ng a joint European Supersonic Research Programme (ESRP).

The next-generation SST is scheduled to be developed in the :arly 21st century, but a broad range of technological break- hroughs will be necessary to permit the aircraft to satisfy the eco- ıomic and environmental conditions indispensable for commer- :ialization. Japan is presently engaged in related research activi- ies by intensively participating in this joint international R&D ɔrogram and playing a prominent role in the SST commercializa- ion.

This article describes the specifications required for the com- nercial aircraft, the basic design studied based on this require- nent, the aircraft design under study in Western countries, and he technological problems under research in Japan for the com- nercialization.

2. Specifications Required by the Market

Various countries planning to develop the next-generation SST ıre conducting surveys to elucidate the market demands by air- ines, and conducting studies on the aircraft's marketability. In Japan, the marketability of the aircraft was studied based on a sur- vey of the specifications required by domestic airlines. The sur- vey revealed that the requirements are a seating capacity of 300 ɔassengers, and a speed of over Mach 2.0, but the cruising dis- :ance is the most vital item. The aircraft must be capable not only ɔf making trans-Pacific flights over a distance of 5,000 nm but ılso direct flights to Europe for a distance of 6,000 nm and, if ɔossible, to fly nonstop to the east coast of the United States (Fig. 1).

The acceptable flight cost is up to 30-50% greater than the ɔresent 747-400 charge. However, more stringent demands are ɔeing raised in foreign countries regarding this cost, which demands due thought. The aircraft design specifications include body dimensions enabling the aircraft to be accommodated without any problem by existing airports and, at the same time, inconveniences were pointed out in the arrangement of passenger doors, as well as poor cabin service.

3. Basic Aircraft Body

Table 1 shows the preferred aircraft design in conformance with the specifications of airline companies. The airport noise demand is set at the demand level of subsonic planes. Fig. 2 shows the design mission on the premise that subsonic cruising is performed over land due to the sonic boom.

About 10% of the designed cruising distance is at Mach 0.95, and subsonic flight is assumed at an elevation of 35,000 ft, with supersonic cruising started from an elevation of 54,500 ft. Flight to an alternative airstrip and 30 min of waiting are included.

The design demands were applied to JADC's configuration and performance evaluation program for SST(CAD) to determine the basic aircraft specifications. Fig. 3 shows the basic aircraft configuration as well as specifications. With a cruising distance of 6,000 nm, the liftoff weight will exceed 1 million lbs, making the aircraft economically unfeasible. Therefore, the specification was set at 5,500 nm.

The engine used on the basic aircraft will be the mixed-flow turbofan (MFTF) engine (see Fig. 4). The engine rear is equipped with a mixer ejector to conform to the airport noise demand.

4. Body Under Study in Western Countries

In the United States, the High-Speed Research Program (HSRP) is being advanced under the leadership of Boeing and McDonnell Douglas with a budget of $2 billion, through which research is being conducted to develop technologies relating to the aircraft body, engine and environmental protection. Fig. 5 shows the annual budget for the program, which is about $240 million annually. The body under study is the Technical Concept Aircraft (TCA) described in Fig. 6. The aircraft cruising speed is Mach 2.4, carrying 310 passengers for a flight distance of 5,000 nm, and the maximum takeoff weight is 335 t. The body is a composite structure consisting of titanium/composite materials.

In Europe, Aerospatiale, British Aerospace and DASA are con-

Technical Problems of Next-Generation Supersonic Transport (SST) and Japan's Policy to Cope with These Problems

(1) Required Specifications		
Seating capacity	:	Minimum 300 (tri class), 350 (two class)
Cruising speed	:	Over Mach 2.0 (TYO-LAX within 4.5 hrs)
Flight performance	:	Minimum 5,000 nm (direct flight to U.S. west coast, if possible 6,000 nm (direct flights to Europe) and 7,000 nm (direct flights to U.S. east coast)
Takeoff/landing performance	:	Less than 11,000 ft (O.K. with the same level as 747-400 at SL and ISA + 20 °C)
Economy	:	Fare within +30 to +50% of 747-400
(2) Body Specifications		
Seat specifications	:	The SST selling point is short flight time, so two class specifications are adequate, but with flights of over 6 hrs, consideration must be given to tri class. The seat pitch may become slightly narrower
Seat pitch/width	:	Pitch F: 60 inch, C: 40-60 inch, Y: 32-34 inch Width F: 20-22 inch, C: 19-20 inch, Y: 17-18 inch
Body dimensions	:	Enabling plane accommodation at existing international airports
Door arrangement	:	Two doors necessary for 300 passengers. The 2nd door to be studied with thought given to the boarding bridge and evacuation system
Dining service	:	The SST flight time will be within 6 hrs on virtually all routes, so a single-meal service will suffice.
(3) Flight Routes		
Destinations	:	Possible candidates in the U.S. will be SFO, LAX, CHI, NYC and WAS, in Europe FRA, LON, PAR, ROM, and in the Asia/Pacific area SIN, MNL, BKK, HKG and SYD. Routes mainly for tourists (such as Hawaii) will not become SST service environments immediately. Short-distance lines will not provide any advantage for SSTs.
Hub flights	:	Hub flights requiring transfers will necessarily raise fares and become undesirable since they will be disadvantageous in competition.
(4) Passenger Attraction Effect	:	With domestic lines, the use of jet planes and the shortening of flight time by 27% was calculated to attract an additional 23% of passengers, but this matter requires restudy.
(5) Airport Compatibility		
Turn around time	:	60 min (same as existing 747-400). With a single passageway and a single Type 1 door, the passenger alighting and boarding time will become critical.
Plane parking	:	The same space as existing 747-400 planes will suffice (45 ° parking system).
Taxiing	:	The aircraft must be able to turn from taxiway to runway with existing facilities.
(6) Others	:	Studies must be given to the influences on the surrounding environment and human beings, and how to cope with emergencies.

Fig. 1. Requirements of airline companies

Item	
Design speed	Mach 2.2
Target cruising distance	11,100 km (6,000 nm),
	including 10% of subsonic cruising
Design number of seats	300 seats
Aircraft type	Horizontal tail plane
Fuselage length	94.5 m (310 ft)
Airport noise limit	Compatible to FAR Part 36, Stage 3

Table 1. Aircraft design specifications

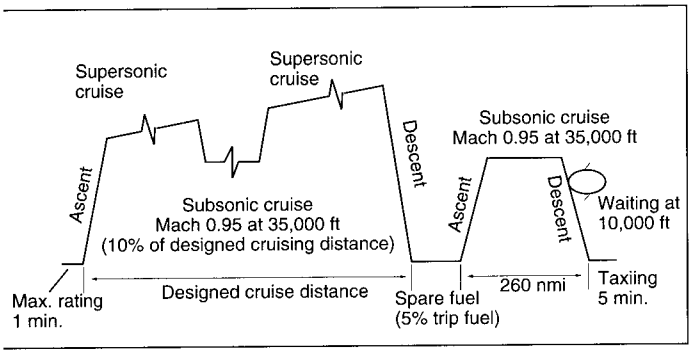


Fig. 2. Designed mission

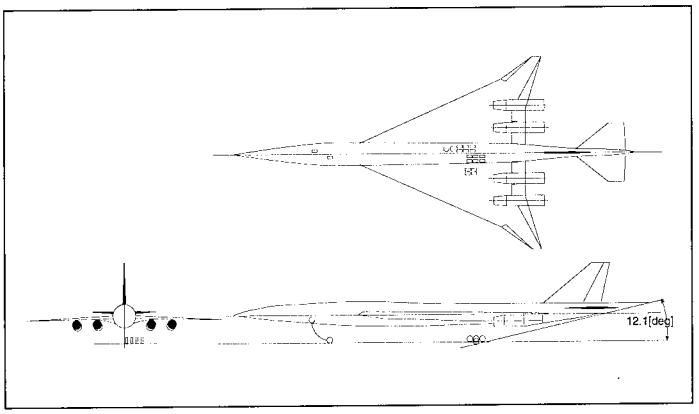


Fig. 3. Plane drawings and specifications of basic aircraft

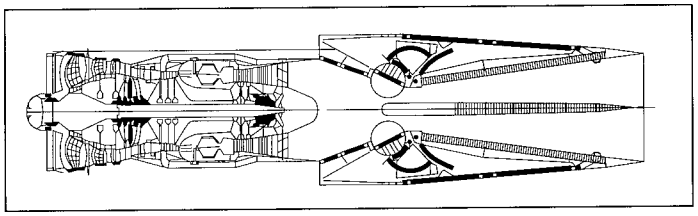
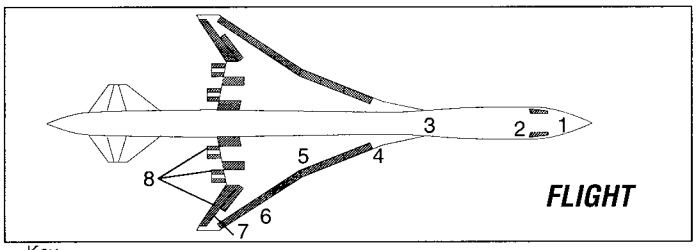


Fig. 4. MFTF engine

Fiscal Year	~'91	'92	'93	'94	'95	'96	'97	'98	'99~	2001~2006
Schedule				Determining the Initial-Stage Aircraft Concept			Commencement of Prototype Research	Commencement of Development (2001)	Acquisition of Type Certification (2006)	
				Environmental Compatibility Technology Survey						
				Demonstration of Technologies to Improve Environmental Compatibility and Economic Development of Body						
Annual budgets ($1 Million)	69	76	117	187	221	246	243	294	398	(Tatal) 1,850
Phase 1	69	76	92	91	63	12				402
* Effect of Engine Exhaust on Atmosphere	18	12	12	11	8					61
* Engine Combustor and Noise Reduction	33	30	30	25	19					137
* Influences of Airport Noise and Sonic Boom	18	18	18	15	13					81
* New Materials for Engine		17	32	40	22	12	(254)			123
Phase 2			25	96	159	234	243	294	398	1,448
* New Materials for Engine			5	8	22	36	41	44	34	190
* Critical Engine Elements			9	18	39	67	74	96	125	428
* Body Structural Materials and Structural Mode			11	26	38	57	63	70	111	376
* Aerodynamics (Body Shape)				18	21	29	28	32	46	175
* Flight Deck System				8	7	19	19	25	29	107
* Technology Coordination and Influences to Environment				7	19	15	18	13	23	95
* Environmental Influence Monitor and Sensor				11	12	12	(11.3)	14	29	78

Fig. 5. Annual budgets for HSRP.

Technical Problems of Next-Generation Supersonic Transport (SST) and Japan's Policy to Cope with These Problems



Key

1 No front visior. EVS cockpit (to be selected)	4 Simple leading-edge (no movement)
2 "767" width forward fuselage, six-abreast capacity	5 Simplified three-piece leading-edge device
3 Main cabin "757" width, five-abreast relatively constant section ---not as area ruled, as had been feared	6 Simplifed one-piece moving leading edge
	7 Spoilers for high-speed roll control
	8 Multi-role elevon/aileron and flap

NASA Technical Concept Aircraft Facts And Figures

Maximum take-off weight	335,000kg	Range	9,200km
Fuselage length	100m	Engine power	220kN
Wingspan	40m	Noise target	Stage 3-3dB
Three-class accommodation	310		

Fig. 6. Description of TCA.

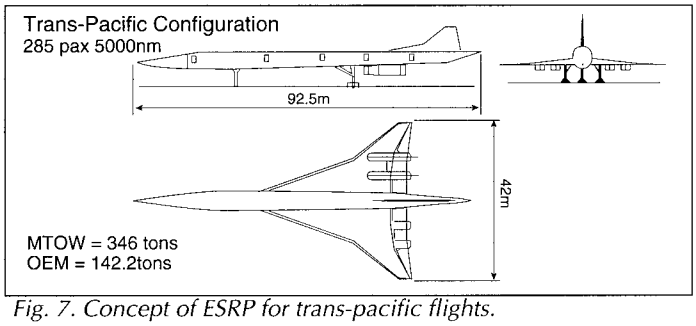


Fig. 7. Concept of ESRP for trans-pacific flights.

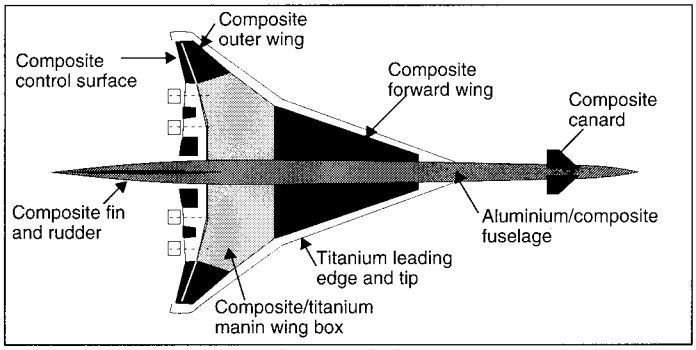


Fig. 8. Candidate structural materials for ESRP.

ducting joint research on the European Supersonic Research Programme (ESRP). Two types of aircraft are under study, one for the trans-Pacific route and the other for a European/Orient route. The former is designed to accommodate 285 passengers, flight distance of 5,000 nm and maximum takeoff weight of 348 t (see Fig. 7). The latter is designed to accommodate 225 passengers, a flight distance of 6,000 m and maximum takeoff weight of 385 t. Both of these planes are designed for a cruising speed of Mach 2.0. Fig. 8 shows the candidate structural materials, and the partial use of aluminum alloy is being studied since the speed is less and the aerodynamic heating alleviated.

5. Technical Probems

Maximum Take-off Weight 350t
Span 42 m
Length 92.5m
285 passengers in 3 class, 6 abreast in tourist and business class
Supersonic cruise mach 2.0

5.1. Innovative Technologies for SST Development

In the CAD program to determine the baseline configuration, technological improvement coefficients are applied that assumes future technological innovation. Regarding materials/structures, aerodynamic force and engine, technological innovation was modelled from Concorde technologies. Firstly, the structural weight was reduced by 28% by using composite materials, the lift drag ratio improved by 23% by improving the aerodynamic performance, and the specific fuel consumption decreased by 3% through the introduction of advanced engine technology. Without these advanced technologies, the maximum takeoff weight will be over 1,000 t with an aircraft of 300 seats, flight distance of 6,000 nm and cruising speed of mach 2.2 (see Fig. 9).

The engine technology improvement values appear to be low, but this situation denotes improvements achieved through coping with the weight increase due to the mixer ejector mounting to suppress noise, which is actually a highly stringent demand. To attain these technological improvements, breakthroughs must be made in connection with various technological problems, as described below.

5.2. Materials and Structure

The next-generation SST is designed for a cruising speed of

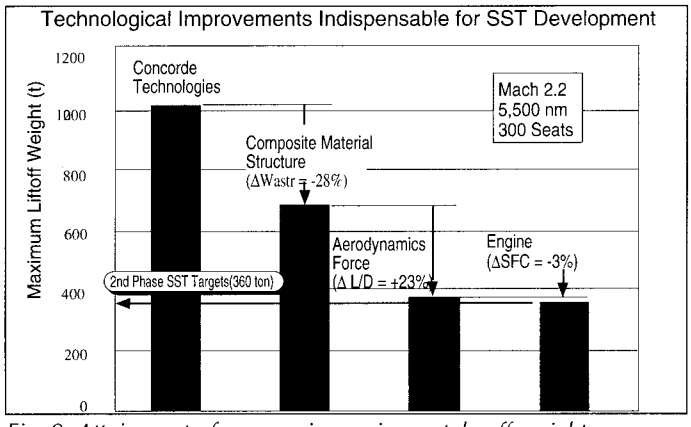


Fig. 9. Attainment of economic maximum takeoff weight.

Mach 2.0-2.4, so the maximum surface temperature due to aerodynamic heating is estimated to be 110-180 °C. Also, a structural weight reduction of about 28% will be necessary, so the plan is to use lightweight heat-resistant composite materials and titanium alloys as the structural materials.

The candidate heat resistant materials are polyimide-based carbon fiber reinforced plastics (CFRP) with long-term heat resistance of over 180 °C and a bismaleimide-based CFRP with a long-term heat resistance of about 150 °C. The former is sub-classified into thermosetting polyimide and thermoplastic polyimide.

The composite material structure is estimated to be used for up to about 60% of the aircraft structure, but the heat-resistant lightweight alloy titanium will be used for the terminal parts of composite material structures, the cores of honeycomb sandwich structures and metal fittings.

To make these heat-resisting composite materials suitable for application to the entire airframe including the main structures, it will be necessary to fully elucidate the characteristics of these materials, and to develop designing and manufacturing technologies enabling the production of quality materials at low cost.

(a) Material Development

The operation of the next-generation SST will be subjected to thermal hysteresis of 20,000-30,000 cycles and thermal aging of 60,000-80,000 hrs, and assuming a scatter factor of 2, then a resistance to thermal hysteresis of 40,000-60,000 cycles over 120,000-160,000 hrs will have to be guaranteed. In addition, with a heat-resistant composite material, the residual strength will become design strength after the material is exposed to such thermal hysteresis, so its characteristics will have to be assessed accurately.

However, even if a thermal load was impressed continuously for one year, this will be only 8,760 hrs, and even if a thermal hysteresis equivalent to one life cycle was impressed, 7-10 years will be necessary. Therefore, unless some accelerated test method is established, a prohibitively long time will be required for the processes from material selection to design data acquisition, or there will be inadequate timing for development. Also, even in durability tests, another crucial matter will be whether an actual environment can be simulated to impress compound cycles consisting of thermal hysteresis and load cycle.

The present studies on several types of candidate heat-resisting composite materials are being conducted to acquire basic data relating to static strength characteristics, fatigue characteristics and heat-resisting characteristics, and to assess the feasibility of conducting accelerated tests. Also, research is in progress on a heat-resistant fiber/metal laminated plate (see Fig. 10) that is designed to improve the damage resistance property by laminating titanium foils and heat-resistant composite materials with the objective of establishing a manufacturing process and to elucidate the damage-resisting properties.

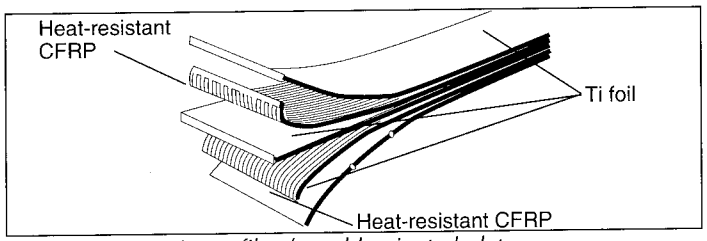


Fig. 10. Heat-resistant fiber/metal laminated plate

(b) Development of Design Technology

To use composite materials in all parts of the aircraft including the body primary structure, the development of damage-tolerant design technology and buckling allowance design technology will be indispensable. Regarding metal structures, the buckling allowance design is a natural design procedure and contributes greatly to reducing the weight of the aircraft structure. However, the mechanism of destruction of composite materials is quite complicated and designing the buckling tolerance necessarily demands the collection of a huge volume of test data, but due to the lack of expertise with complex material structures, the buckling tolerance design technology is as yet undeveloped. However, the application of this technology cannot be evaded in order to attain a weight reduction of 28%. In addition, damage-tolerant design in connection with composite materials will involve not ordinary cracking as with metallic materials but delamination to render the problem much more complicated and difficult to cope with.

Unless these design technologies are established and introduced, an economical airframe strucure cannot be fabricated and the SST cannot be commercialized. These design processes are not fully established even in connection with composite materials such as epoxy plastics, so establishment through this research project will allow application to designing subsonic planes. However, in this research project, it will be necessary to consider buckling/aging through heating, so the establishment of these technologies will be much more difficult than technologies for subsonic planes.

(c) Low-Cost Fabrication Technology

In order to fabricate SST airframes economically, the development of technologies to fabricate structures at low cost will be indispensable. In particular, the conditions for forming heat-resisting complex materials will be approximately 15 atmospheric pressure at over 300 °C compared with the forming of epoxy-based CFRP of 2-3 atmospheric pressure at over 100 °C. In addition, the forming pressure will be greater by 5-6 times, so jig misalignment is possible during the hardening process, and producing jigs capable of resisting misalignment will also be quite diffi-

Technical Problems of Next-Generation Supersonic Transport (SST) and Japan's Policy to Cope with These Problems

cult. The jig structures will be more complicated since they will have to be pressurized uniformly. The forming temperature is also quite high, so auxiliary forming materials such as vacuum packing and sealing materials will have to be employed at the limiting conditions of use, making handling quite intricate. In addition, polyimide-based prepregs generate a large volume of gas in the process of hardening, so when using large prepregs, the construction for gas evacuation will become quite complicated, making forming increasingly difficult (see Fig. 11).

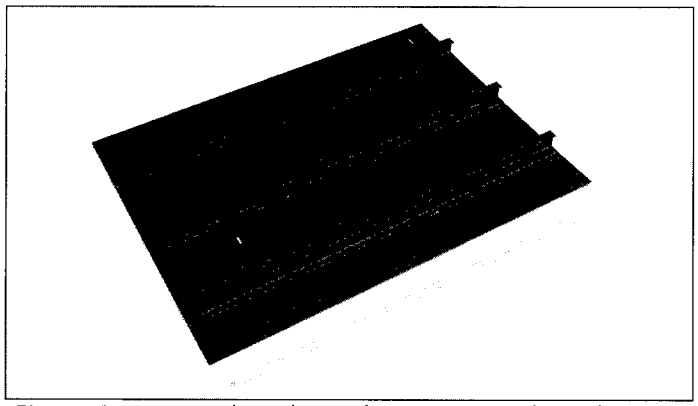


Fig. 11. Prototype Polyimide Reinforcing Structural Member.

The previous technical matters relate to the autoclave forming process that is being applied widely to form composite materials, but non-autoclave forming processes are also available for cost reduction. For example, there is the resin transfer molding (RTM) process in which dried fibers are placed inside a closed mold, poured with non-hardened resin from the outside for impregnation and setting of the resin, the resin film infusion forming process in which a film of non-hardened resin is laid in a closed mold, dried fibers laid over the film, then the temperature raised to soak the resin into the fibers and to harden the mixture, the pultrusion forming process in which a on-hardened resin is impregnated on fiber-reinforced bundles, then hardened continuously by passage through a heated die, and the direct consolidation forming process in which a thermoplastic composite material is laminated directly on a die, then hardened at the same time.

Titanium alloy, a lightweight heat-resisting metal, is also used widely for producing metal fittings, in which case cost reduction by high-speed grinding, etc is a vital requirement (see Fig. 12).

5.3. Aerodynamics

Improving the lift to drag ratio during supersonic cruising will demand optimization of the aircraft wing shape, drag reduction through coordinated wing/nose designing, and drag reduction through wing warping/body area rule application. Also, for airport noise and aircraft size reduction, the takeoff lift to drag ratio

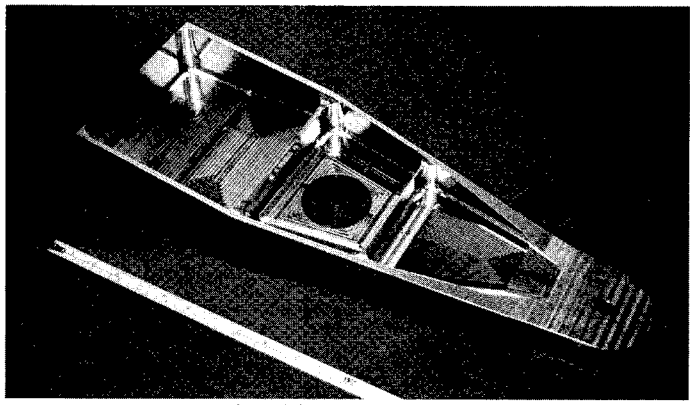


Fig. 12. Prototype product fabricated by high-speed titanium alloy grinding.

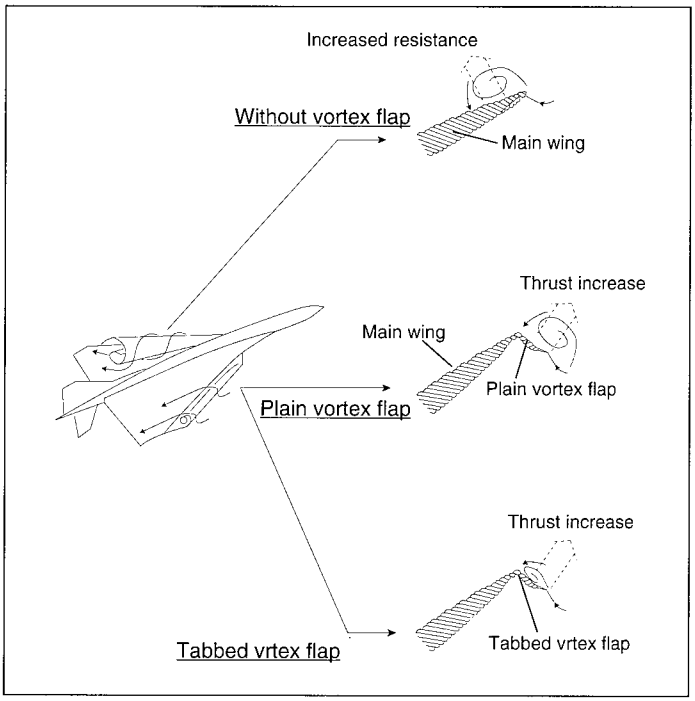


Fig. 13. Vortex flap.

will have to be improved considerably, making research vital in connection with high lift systems such as the vortex flap (see Fig. 13). Intense drag changes due to intake unstart is a problem characteristic of SSTs, and the accurate estimation of aerodynamic heating during supersonic flights is an element that exerts a big influence on material selection, and on structural weight and fabrication cost.

More recently, as the means for estimating the aerodynamic characteristics, the computational fluid dynamics (CFD) method has been adopted in place of the wind tunnel test (see Fig. 14).

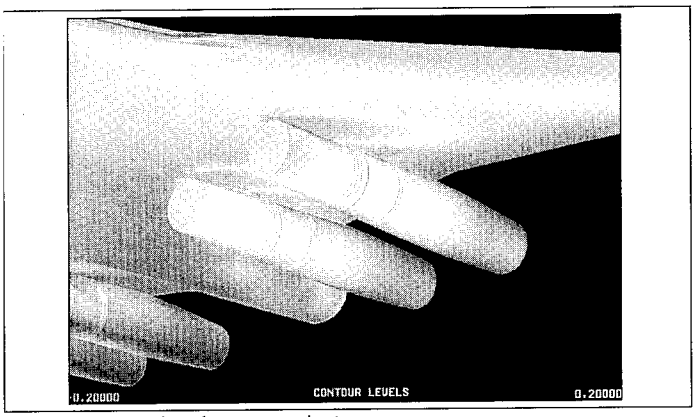


Fig. 14. Example of CFD Analysis.

However, in view of the existing backwardness in supersonic technologies, the unique Japanese CFD code has not been verified through flight tests.

The objective of the Subscale Supersonic Experimental Aircraft development project presently being implemented by the National Aerospace Laboratory of the Science and Technology Agency is to improve the aerodynamic design technology by computational fluid dynamics (CFD). Expectations are placed on the substantiation of the CFD code necessary for the overall aerodynamic designing of SSTs as well as verification through wind tunnel tests and flight experiments. Further, the development of an optimization program for aerodynamic shapes through CFD will be highly beneficial for use as a design tool.

5.4. Related Equipment

To secure good pilot vision during Concorde takeoff and landing, a nose droop mechanism was adopted. This system required a large weight increase so elimination of the nose droop mechanism as well as all weather capability is anticipated by the synthetic vision system (SVS). However, since it will be a windowless system, vital basic technologies will consist of establishing compatibility with the pilot and securing system reliability.

The supersonic wing is thin, so the accommodation of the aileron and leading-edge wing flap actuators inside the wing will be an issue. Using protuding actuators and fairings as with Concorde or subsonic aircraft in general will increase the drag, and increase the aircraft size (see Fig. 15). To cope with this situation, accommodation inside the wing with a rotary actuator is under study. Incidentally, downsizing of actuators by introducing a high-pressure hydraulic system will be necessary at the same time.

The SST external surface will undergo aerodynamic heating in supersonic cruising. With a subsonic aircraft, ram air is taken in for engine oil and mounted equipment cooling as well as for cabin air conditioning, but with a supersonic aircraft, the air in the proximity of the body will be heated, so adequate cooling cannot be achieved with ordinary ram air. With Concorde, a huge mass of fuel is employed as a heat sink, but when the cruising distance becomes longer, simply using the fuel mass would become insufficient, and an efficient heat control system becomes necessary.

5.5. Engine

The engine for SSTs is under research through the Super-/Hypersonic Transport Propulsion System Program (HYPR Program) implemented by the Ministry of International Trade and Industry, and the results will be applied to the development of the next-generation SST. A vital theme in the development of the SST concerns the mounting of a mixer ejector to decrease aerodynamic noise, for which a major technical theme is how to suppress the overall engine weight.

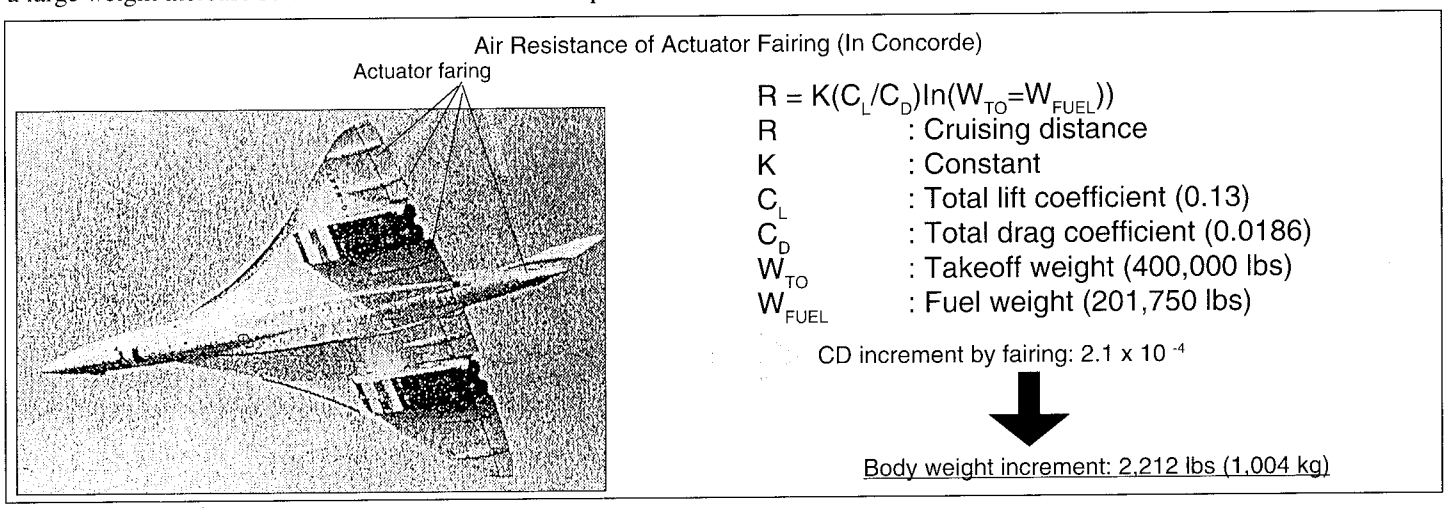


Fig. 15. Necessity for rotary actuator

Technical Problems of Next-Generation Supersonic Transport (SST) and Japan's Policy to Cope with These Problems

Also, it will be necessary to minimize NOx discharge from the standpoint of protecting the ozone layer, so improvement of fuel combustion technology is needed. To establish these technologies and to minimize the body sizes of SSTs, it will be necessary to lower the specific fuel consumption (SFC) ratio and to lighten the engine weight through the use of advanced materials.

5.6. Environmental Compatibility

The environmental problems which were raised in connection with Concorde were airport noise, sonic boom and NOx discharge. The commissioning of the next-generation SST assumes compatibility with these environmental matters.

Regarding airport noise, subsonic planes are governed by Chapter 3 prescribed by ICAO, but no such standards have been established as yet for SSTs, so the ICAO Committee on Aviation Environmental Protection (CAEP) is presently studying the noise standards for SSTs. Noise reduction methods include mounting a mixer ejector, and improving the drag-lift ratio at time of takeoff and landing with a high-lift system.

Data have been collected on human acceptance using a sonic boom box (see Fig. 16) and proper measures are being studied in connection with the perceived level (PL dB). The adoption of a low boom in body design involves a big increase in drag, so this method appears inconceivable for application to next-generation SSTs. Therefore, as with Concorde, the adoption of the method of subsonic overland flights is conceivable.

Regarding the adverse influences exerted on the ozone layer by the discharge of NOx from engines, estimates are being made by various countries through analysis with atmospheric models, then compared with observations with artificial satellites. According to the results of these estimates, the influence on the ozone layer by SSTs will lie within the domain of the natural changes of the ozone layer and is conceived to be negligible, as long as the emission index (EI), or the equivalent NO_2 g-number of the NOx emitted by the combustion of 1 kg of fuel lies below 5. Therefore, improving the engine combustion technology to this target is required.

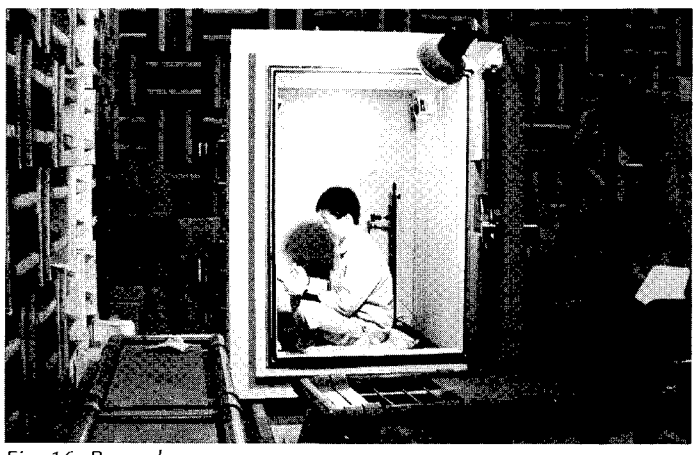


Fig. 16. Boom box

6. Advancement of Research

The commercialization of the next-generation SST demands technological breakthroughs of a wide range of related technologies. At present, research is primarily being advanced under consignment by the Ministry of International Trade and Industry, but the Science and Technology Agency has also instituted a subscale experimental aircraft R&D project, developing related technologies for the future international joint development .

There is only a single target, so it will be vital for Japanese research organizations to produce complementary results in cooperation. Broadly classified, the Science and Technology Agency is advancing research primarily in connection with fundamental and scientific technologies, and the Ministry of International Trade and Industry advancing research in connection with designing and manufacture. The research advanced cooperation between the ministry and the agency is being started in various fields, and a setup is being established to advance research in coordination.

7. Postscript

The development of the next-generation SST offers Japan a good opportunity to engage in the development of civil aviation aircraft on an equal footing with Western enterprises, so it will be vital for Japan to foster adequate potential in technological development in the primary stage. Especially when considering the futureshare of production, it would be appropriate to place emphasis on the development of related materials and structures, which stands out as a field in which Japan has a wonderful record of performance and will provide a good opportunity for further progress.

Reference Materials

(1) Report of results of Supersonic Transport Developmental Survey, FY 1996 Next-Generation SST Developmental Survey, compiled by Japan Aerospace Industrial Office, March 1997.
(2) NASA Unveils Supersonic Concept Aircraft, Flight International, 17-23, April 1996.
(3) P.K. Green, M. Pacull, H. D. Reimers, European 2nd-Generation Supersonic Commercial Transport Aircraft, ICAS 96-4.4.1, 8-13, September 1996.
(4) P. Ermanni, I. Braidley, B. Ribere, Structure Design Concepts for the Next-Generation Supersonic Transport, ICAS-96-5.1.2, 8-13, September 1996.

Present State and Future Outlook of the Joint International R&D Project on Hyper-sonic Transport Propulsion Systems (HYPR Project)

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Managing Director,
Engineering Research Association for Super/
Hyper-Sonic Transport Propulsion

1. Introduction

To replace the supersonic transport Concorde that is currently in commercial service at a speed of mach 2, basic research is being advanced by several countries on the aircraft and engine of a supersonic transport with a speed of mach 2-2.5, and a commercial transport is expected to be realized in the early 21st century. In Japan, this project (the HYPR Project), is being advanced by the Agency of Industrial Science and Technology of the Ministry of International Trade and Industry from FY 1988 as a large-scale project (renamed the Industrial Science and Technology R&D Project in FY 1993) to establish technologies indispensable for a propulsion system for a more advanced hyper-sonic transport with a speed of mach 5, and related research is being advanced through consignment by the New Energy and Industrial Technology Development Organization (NEDO).

2. World Trends

(1) In the U.S.

Phase 1 of the NASA High Speed Research Program (HSR1) funded with US national showed that it is possible to develop engine satisfying noise standard. At present, the program is in its subsequent Phase 2 (HSR2), research will be completed by the year 2001, and the development of the aircraft is scheduled for putting the aircraft into commercial operation around the year 2007. In November last year, in joint research with Russia, flight tests were conducted using the Tu-144. The aircraft targets are a speed of mach 2.4, a seating capacity of 300 passengers and a range of 5,500-6,500 nm.

(2) In Europe

In West Europe, Aerospeciale of France, British Aerospace of Britain and German Airbus of Germany are striving to coordinate their supersonic transport research activities, joint research to commercialize an engine for the next-generation Concorde by Rolls Royce of Britain and SNECMA of France is being bolstered, and a European Supersonic Transport Research Program (ESRP) was established in April 1994 by EU and other countries to solicit research funds, but the necessary research budget of about $500 million has not been allocated as yet.

The aircraft cruising speed is mach 2, a comparatively low target, the seating capacity of 250 passengers, and the maximum range of 5,500 nm.

3. Outline of Research Programs

In the HYPR Program, research is being advanced on the following themes establishing technologies indispensable for a propulsion system enabling flights from a low speed to a speed of mach 5, also featuring excellent specific fuel consumption, low noise and minimal adverse influences to the environment:

(1) R&D on ramjet technology.
(2) R&D on highperformance turbojet engine.
(3) R&D on measurement and control systems.
(4) R&D on total system.
(5) R&D on ultrahigh temperature gas generator.

Regarding these themes, basic research will be proceeded with a Ten-Year Program (Table 1), while system experimental fabrication and tests are already in progress or scheduled in connection with the ramjet technology, turbojet system and combined cycle engine.

The results of these R&D projects were presented at international symposiums held on two occasions previously with the participation of seven domestic and foreign member companies in these symposiums, and project interim evaluation is under way.

4. Progress of Research Projects

(1) R&D on Ramjet Technology

Research on a ramjet technology enabling supersonic flights in a wide range of speeds of mach 2.5-5.0 is being carried out by dividing the project into research on ram combustor and on the ramjet system.

1) Research on Ram Combustor

Research on combustion control of the ram combustor has continued improvements on a block type combustor coordinating a V-gutter type and main combustor type, and target levels were achieved for combustion efficiency and pressure loss reduction.

To achieve the reduction of pollution, an improved combustion nozzle was designed and fabricated to decrease the emission of NOx that is the greatest impart on atmosphere when flying at high speeds, and the results of mixed fuel performance tests and inlet air heating combustion tests revealed that NOx emission can be decreased substantially by improvement of fuel injection. Also, numerical analysis by directing attention on fuel jetting with a basic test combustor, and an improved fuel nozzle was proposed for NOx reduction.

In research on cooling structures, a prototype heat-resistant complex material liner was used to conduct ram combustion basic tests to advance research on the cooling structures of ram combustors in which combustor outlet temperature may run as high as 1,900 °C, and the liner was evaluated for application to combustors.

2) Research on Ram Jet System

A facility belonging to United Technologies, Inc. was used to conduct direct connection tests which enable dimensional and shape tests to be conducted at near actual states, through which the combustion limits and turbo ram dual mode combustion performance were confirmed at various air temperatures and flow speed conditions, and data were acquired which will be neces-

Present State and Future Outlook of the Joint International R&D Project on Supersonic Transport Propulsion Systems (HYPR Project)

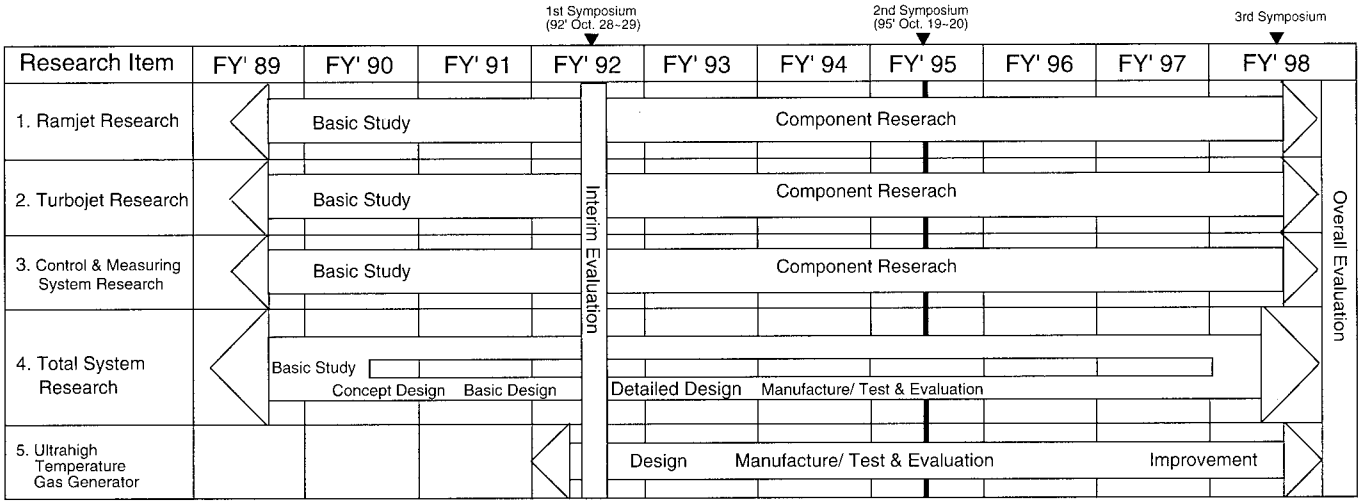


Table 1. Outline of the 10-year HYPR program

sary for designing a ram combustor for a combined cycle engine for which high-altitude performance tests will be conducted in FY 1998.

In FY 1995, a ram jet testing facility belonging to the Kakuda Research Center of the National Aerospace Laboratory, Science and Technology Agency, was used to conduct engine performance tests under the flight conditions of mach 5 by using compact models including intake devices, and valuable data were acquired in connection with technology to integrate various engine structural elements such as supersonic intakes, ram combustors and exhaust nozzles.

(2) Research on Highperformance Turbojet Engine

Research on turbojet engine structural members, such as fans, compressors, combustors, high-pressure turbines and low-pressure turbines, is being advanced for performance and efficiency improvement as well as for atmospheric pollution reduction. These structural members were assembled into a prototype engine, and target performances attained while confirming the performance of the entire system. The target performances of these structural members are as described below.

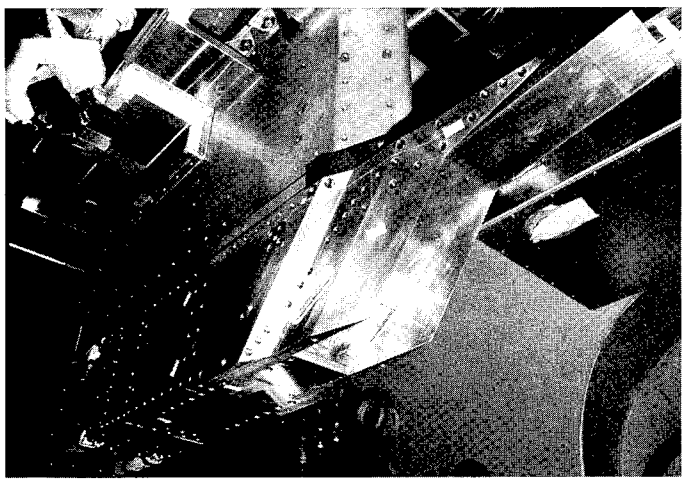


Fig. 1 Ram jet testing facility (Kakuda Research Center of NAL)

1) Attainment of a pressure ratio of 2.6 with a two-stage fan
2) Attainment of polytropic efficiency of 91%
3) Combustor: The target is to develop a high-performance combustor operating with stability over a wide speed range from the stationary state on the ground to flights at mach 3, and which reduces the NOx emission to one-tenth of conventional technical levels at mach 3.
4) Highpressure Turbine: The targets are a turbine inlet temperature of 1,700 °C and cooling efficiency of 0.62.
5) Low-Pressure Turbine: The target is the development of a cooled turbine with an inlet temperature of 1,300 °C.
6) Ultrahightemperature Gas Generator (HTCE)

The ultrahightemperature gas generator is the nucleus of the turbojet engine and is equivalent to a high-pressure subsystem (core engine). The turbine inlet temperature is set at a high level of 1,700 °C to enable the generator to display a high performance even when subjected to aerodynamic heating when flying at high speeds, and for this, precursory research is in progress to introduce high-performance single crystal superalloys, powder metallurgy, cooling technology and computerized fluid dynamics (CFD).

To verify performances and especially to enable high-speed flights to be simulated in early FY 1996, the suction air was heated to a level of 300 °C, the turbine inlet temperature raised to 1,600 °C, and operation commenced. Further, in FY 1997, the design was improved to permit tests to be conducted at a

turbine inlet temperature of 1,700 °C. The strengths of the constituent parts of the turbine blade and vane were analyzed in the state in which cooling was verified through basic structural cooling tests. For outlet guide vanes, studies were advanced on the applicability of thermal barrier coating, and regarding the combustor casing and turbine casing materials featuring high heat resistance were selected.

7) Turbojet Engine

To achieve low noise on the ground and high efficiency in high-speed flights, a variable bypass turbofan engine introducing the variable cycle concept was tested to establish the technologies necessary to develop a turbojet engine capable of excellent performance over the wide range from take off to flights at mach 3. The experimental engine was fabricated experimentally and tests conducted from FY 1994. During the period from FY 1996 to early FY 1997, high-altitude performance tests (ATF tests) were conducted by General Electric (U.S.) (see Fig. 2), and simulated operation was performed successfully at an altitude of 60,000 ft and flight speed of mach 3. In parallel, success was achieved in the measurement of the windmill start characteristic that is vital for interswitching from ram mode to turbo mode, in preparation for operation of a combined cycle engine. Rolls Royce of the U.K. is planning to conduct noise suppression tests with a turbojet engine (see Fig. 3).

(3) Research on Measurement and Control

Research is in progress on a Full Authority Digital Electronic Control (FADEC) System for optimum control of engines used at high working ranges of altitudes of up to 90,000 ft and speeds from stationary state on the ground to mach 5, and on an electronic light measuring system to measure the states of hightemperature engines in which the ram combustion temperature of 1,900 °C.

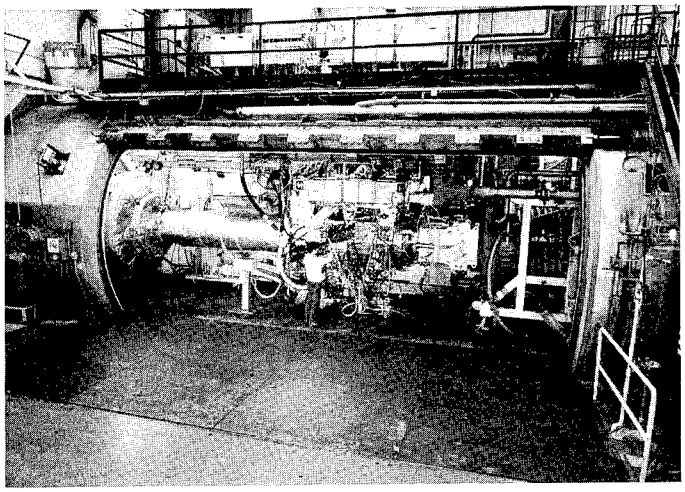


Fig. 2. View of turbojet engine (for ATF tests) at GE Cincinnatti, U.S.

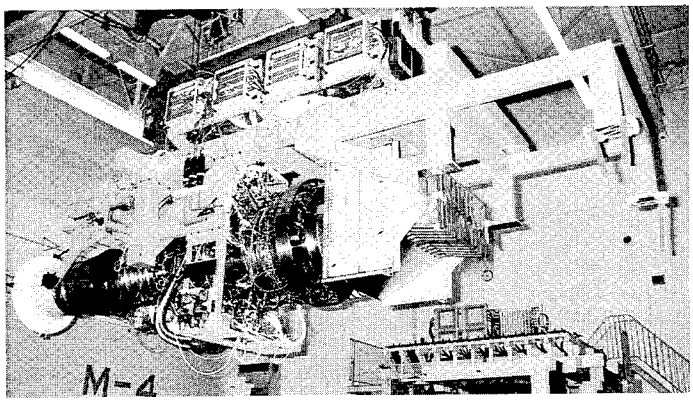


Fig. 3. Turbojet engine for noise suppression tests, Rolls Royce, U.K.

(4) Research on Total System

1) Research on CFD Software

Research is in progress to develop CFD software that would enable innovative designing of high-performance engine elements, also to establish advanced designing means.

Regarding fans, compressors and turbine elements, the CFD software developed for these systems was applied and verified through testing, so that the effectiveness of three-dimensional viscosity analysis software was confirmed. By FY 1996, three-dimensional viscosity analysis software were coordinated and established as a tool for design and analysis.

The results of analysis through tests on core elements (compressors, turbines, etc.) will be verified to acquire outlooks for application to design, while support will be offered for the development of engine elements and for conducting high-altitude performance tests. Fig. 4 shows an example of CFD analysis results.

2) Research on Intake

In the turbo range (mach 0-3) and the ram range (mach 2.5-5), research is in progress on intakes with high total pressure recovery rates and, based on these results, research will be advanced on combined intakes which operate with stability in the speed domains from the stationary state on the ground to flights at up to mach 5 which have the channel shape variable mechanism, boundary layer control mechanism and flow rate adjustment mechanism.

To improve the aerodynamic shapes and bleeding conditions of combined intakes, and through the results of wind tunnel tests in Japan and large-scale wind tunnel tests conducted at the ONERA institute, France, and the total pressure recovery ratio that was the specific target of intake research in this project was attained in the domains of mach 2, 3, 4 and 5 by FY 1996. In

Present State and Future Outlook of the Joint International R&D Project on Supersonic Transport Propulsion Systems (HYPR Project)

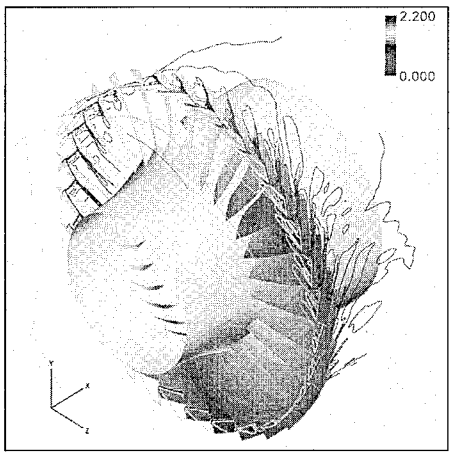


Fig.4 Example of multivane analysis results by three-dimentional viscosity analysis software (Mach contour by Transonic Fan Distribution Analysis)

particular, a total pressure recovery ratio of 53%, which exceeded the target performance, was attained at mach 5. Fig. 5 shows the model used in the combined intake wind tunnel tests.

3) Research on Exhaust Nozzle

Research on the aerodynamic and variable properties of exhaust nozzles used calculations made by numerical analysis to acquire variable schedules of ejector two-dimensional nozzles capable of treating intake bleed flow rates in the domains from the stationary state on the ground and up to flights at mach 3. Also, based on the test method established in FY 1994, elements were tested with subscale models. These estimate calculations based on numerical analysis were confirmed to agree well with element tests.

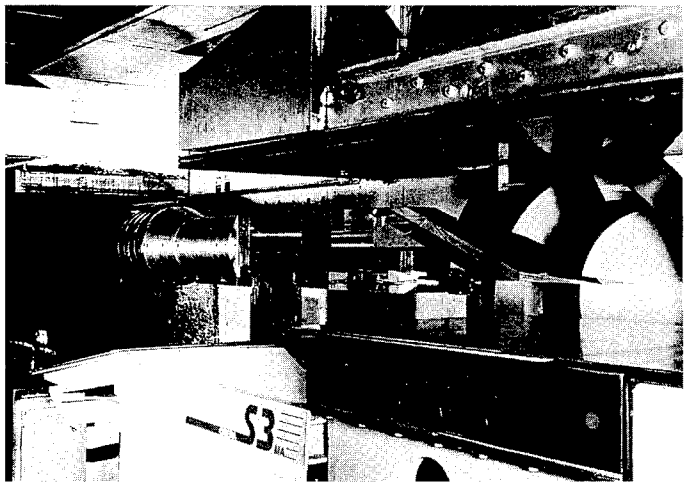


Fig. 5 Fitting of Intake on wind tunnel testing model at the ONERA laboratory in France

Research on combined nozzles conducted CFD analysis on two-dimensional CD nozzles equipped with ejectors which were selected as the target combined nozzles. It was confirmed that a thrust efficiency of 95% can be attained that is the target in flights of up to mach 5. Cooling performance tests were conducted of air induced from slots to acquire data for designing cooling systems for use in the domain of supersonic flights, and it was confirmed that the cooling structures of two dimensional CD nozzles equipped with ejectors were satisfactory at maximum gas temperatures of up to 1,900 °C.

4) Research on Noise Reduction

Research is being advanced to elucidate the mechanism of generation of jet exhaust noise and fan noise which are the principal noise factors of supersonic transports, with the objective of establishing technologies for noise reduction conforming to the noise regulations prescribed by ICAO.

Regarding jet noise, a sample mixer ejector nozzle and ancillary parts fabricated in conformance with optimization studies were used and coordinated noise tests conducted at the U.K. Defense Research Laboratory (DRA) in FY 1995, including takeoff flight tests, and the effects of a noise absorption liner was also evaluated. To reduce fan noise, based on the results of analysis of principal noise causes and subsequent to noise tests, a noise absorption panel fitted with an intake and a fan case was designed.

At Rolls Royce in the U.K., a sample mixer ejector and noise absorption liner for mounting on a turbojet engine are under fabrication for use in engine noise tests. Fig. 3 shows the turbojet engine for the noise tests. Also, based on the results of these tests, simulated in-flight tests will be conducted at CEPRA, France, within the same fiscal year to acquire noise reduction design data, while model tests are also to be conducted to select an optimum mixer ejector mode for the HYPR target engine.

5) Research on Cooling and New Material Application Technologies

For the realization of lightweight engines with turbine inlet temperatures as high as 1,700 °C and ram combustor outlet temperatures as high as 1,900 °C, research will be advanced to commercialize new materials featuring excellent heat resistance and oxidation resistance properties, also heat shielding coating and cooling techniques to support these materials and coatings.

Research of new material application technologies, to enable these new materials to be applied to the fabrication of combustors and turbine nozzles, was conducted in connection with heat-resistant composite materials, and a C/SiC composite material was formed by the chemical vapor infiltration (CVI) technique, based on the knowledge acquired up till FY 1995 and by using a carbon fiber fabric formed by the braiding method similar to that applied earlier to experimentally produce ram combustor com-

posite material liners. Data were acquired to evaluate the properties of materials and toassess applications. CMC matrix synthesis experiments by CVI elucidated the temperatures and pressures influencing matrix synthesis by changing the temperatures and pressures within a temperature domain (1,000-1,100 °C) lower that those of the synthesizing conditions by FY 1995. Tests to evaluate the characteristics of Cr-based ODS alloys were conducted successively in FY 1995.

Low-pressure turbine blade and disk tests were advanced to acquire data relating to their materials. In connection with ceramic coatings, the reproductivity and soundness of film forming were confirmed, and simulated tests were conducted to evaluate the performance of fabricated equipment. Tests were also conducted on carbon/carbon composite materials.

6) Research on Combined Cycle Engine

This engine mode is optimum for planned flight missions, so basic and detailed designing and fabrication are being advanced confirming the integrated technologies for a coaxial tandem type combined cycle engine that is compatible with the altitudes of the turbo-based and ram-based engines.

Performance analysis of the combined cycle engine will be advanced by conducting studies on the engine operation, maneuvering as well as control logic based on the regular and non-regular characteristics in their turbo mode and ram mode as well as in their switching modes, and by taking into account the results of tests on a prototype turbo jet engine.

Further, a test plan will be drafted for conducting function tests and high-altitude tests at a maximum speed of mach 3.0 which are scheduled for FY 1997 and FY 1998, in parallel with engine performance analysis. Fig. 6 shows the combined cycle engine (computer graphics).

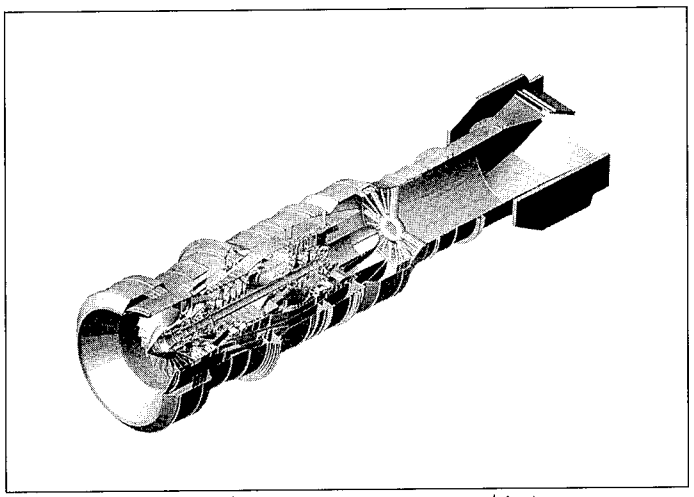


Fig.6 Combined cycle engine (Computer graphics)

5. Participation of Foreign Manufacturers

(1) Setup for Joint Research

The participants in this HYPR Project are the Ministry of International Trade and Industry and the national research institutes belonging to the Engineering Research Association for Super/Hyper-Sonic Transport Propulsion System (HYPR) established in February 1990 by the three domestic enterprises of Ishikawajima-Harima Heavy Industries, Kawasaki Heavy Industries and Mitsubishi Heavy Industries, while in February 1991, the world's big four aircraft engine manufacturers, United Technologies Corp. (UTC/U.S.), General Electric (GE/U.S.), Rolls Royce (RR/U.K.) and SNECMA (SNECMA/France) concluded a joint R&D contract with the New Energy and Technical Development Organization (NEDO).

To implement the research project in close liaison between the three domestic enterprises and the four foreign enterprises, a council consisting of eight consigned enterprises including research organizations, and a Technology Committee for promoting technical cooperation were established and are presently engaging actively in related activities (see Fig.7).

2) Contents of Joint Research

National research institutes are primarily engaged in fundamental and preemptive research, while in the sector of applied technologies, private enterprises are in charge of building a prototype testing elements and systems.

The three domestic enterprises are compiling the technical results of overall promotional systems and implementing research in connection with principal technical issues, while foreign manufacturers with rich technical expertise in the sector of aircraft engines are engaged in the analysis of the design results of domestic manufacturers and conduct tests using large-scale facilities on ram combustors and high-altitude performance tests in which the Japanese participants lack experience.

For example, GE conducted design analysis in connection with a turbojet engine conceptive design, basic design to detailed design drafted by the three Japanese enterprises, and GE participated in the design and manufacture of the high-temperature lubrication system. UTC participated from the beginning of the compound cycle engine conceptual study as well as in ram part designing and fabrication operations.

UTC participated in research on the ram combustor cooling mechanism, SNECMA in research on the combustor NOx emission reduction, and Rolls Royce in research to reduce NOx emission of the turbo combustor. ONERA (a French national research laboratory) participated actively in research on the air intake for the supersonic transport by using its testing facilities.

Present State and Future Outlook of the Joint International R&D Project on Supersonic Transport Propulsion Systems (HYPR Project)

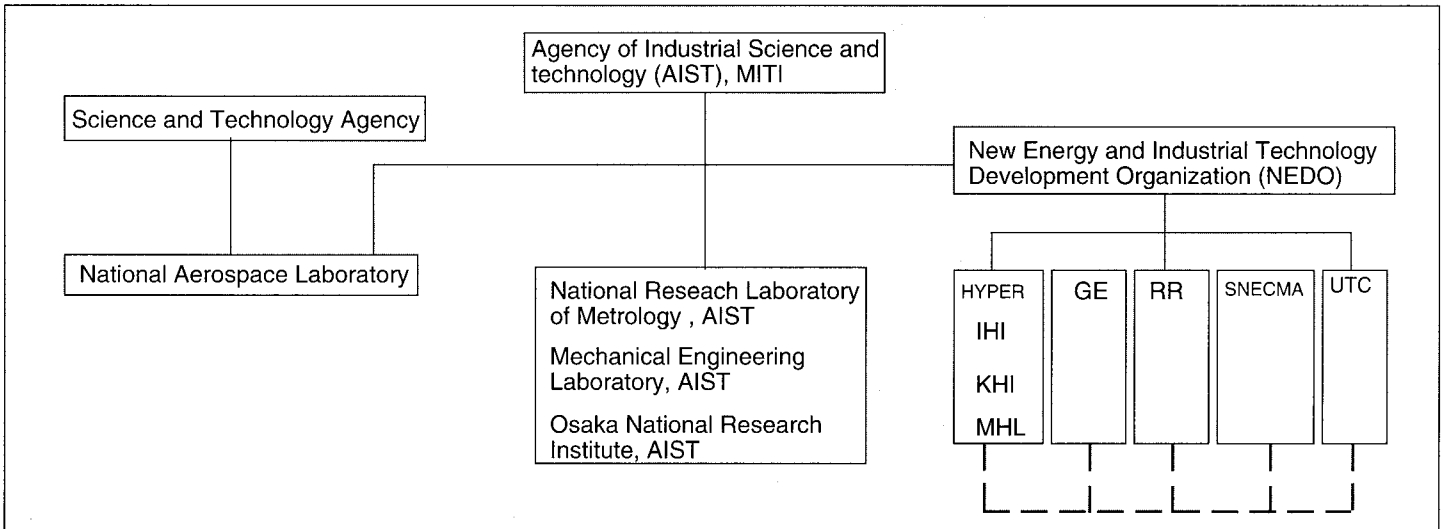
In addition, UTC provided its ram combustor performance testing and research facility, and RR utilized its facilities and participated jointly with SNECMA in the turbojet engine noise tests as well as in the flight effect evaluation tests conducted at CEPRA Laboratories, France. GE utilized the facility and was in charge of the engine high-altitude performance tests, and a high-altitude performance test on a prototype combined cycle engine is scheduled for the latter part of FY 1998.

6. Postscript

The HYPR Project has entered into its 9th year, and the R&D phase in Japan and in other countries is shifting from basic R&D to system R&D, and great efforts are being made to attain scheduled targets.

This is a joint international R&D project, and is proceeding smoothly. During the period from December 1996 to February 1998, were conducted sucessfully at the ATF of GE The high-altitude performance tests of a turbojet engine at mach 3 in Cincinnati, U.S.A. In addition, large-scale tests are scheduled in foreign countries such as the turbojet engine noise tests to be conducted by Rolls Royce, the ATF tests (combined cycle engine high-altitude performance tests) and HTCE (ultra-high-temperature gas generator) TIT 1,700 °C test to be conducted by GE, and the intake tests to be conducted by ONERA of France, making it necessary for Japanese aircraft manufacturers to maintain even greater liaison with foreign enterprises.

This research project is a link of the Supersonic Transport Propulsion System R&D Program that is being advanced through the Industrial Science and Technology R&D System of the Agency of Industrial Science and Technology, Ministry of International Trade and Industry, and is being implemented under consignment by the New Energy and Industrial Technology Development Organization (NEDO).



R&D Setup
This research project is being implemented through consignment by NEDO, and is an international R&D project characterized by the participation of leading foreign engine manufacturers and the particiation of HYPR consisting of domestic engine manufacturers, based on a NEDO consignment contract. To promote lateral liaison between consigned enterprises, a Union and a Deliberative Council (including a Technical Committee) have been established, consisting of the union, three domestic enterprises and four foreign enterprises.
Also, based on a request by the Agency of Industrial Science and Technology (Ministry of International Trade and Industry) to the Science and Technology Agency, four research institutes have participated in this research project, the National Aerospace Laboratory of the Science and Technology Agency, and the National Research Laboratory of Metrology, the Mechanical Engineering Laboratory and the Government Industrial Research Institute, Osaka of the Agency of Industrial Science and Technology.
The Deliberative Council has so far held 12 deliberative meetings and 16 technical committee meetings with the participation of program managers and expert engineers belonging to the consignees, and active opinion exchanges are being conducted with the participation of governmental observers. Recently, a deliberative meeting and technical committee meeting was held in January 1997 in Cincinnatti, U.S., with the cooperation of GE.

HYPER: Engineering Research Association for Super/Hyper-Sonic Transport Propulusion System
IHI: Ishikawajima-Harima Heavy Industries Co., Ltd.
KHI: Kawasaki Heavy Industries,,Ltd.
MHI: Mitsubishi Heavy Industries, Ltd.
GE: General Electric Company
RR: Rolls-Royce plc
SNECMA: Société Nationale d'Etude et de Construction de Moleurs d'Avation
UTC: United Technologies Corporation

Fig.7 Setup for joint research and development.

Trends in Aircraft Composite Material Technologies and Outlook on Smart Composite Structures

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R & D Institute of Metals and Composites
for Future Industries

1. Trends in Aircraft Composite Materials

Since the dissolution of the cold war between the United States and Soviet Russia, the military budgets of industrially advanced countries have been cut drastically. Consequently, the application of composite materials to aerospace vehicles, especially commercial aircraft, influenced by the global recession and stagnant growth of air transport, has deviated considerably from the optimistic upward curve estimated during the period from the latter half of the 1970s to the 1980s and now requires downward revision.

By far the biggest cause is the disadvantage of cost competitiveness (affordability) faced by composite materials compared to present aluminum structures, reflected in the weight reduction to cost aspect that is the conventional determining index, plus the operating cost and environmental harmony. Therefore, the biggest problem facing advanced composite materials is cost improvement, which imposes stringent demands on the conventional weight reduction to cost aspect, underpinned by the need to reduce design and manufacturing costs, and reduce maintenance costs and technology development to achieve environmental harmony.

Improvements in material performance constitutes one form of breakthrough, but the technologies conducing to this breakthrough depend on the projection of conventional technologies, so the development of creative design and manufacturing technologies are required.

1.1. U.S. R&D Program to Develop Low-Cost Composite Materials

In the United States, research programs to develop low-cost composite materials for aircraft have been implemented successively on a national scale primarily by NASA and the Air Force from 2-4 years ago. Symbolic of these programs is the clarification of the developmental targets and the establishment of specific targets, such as actual aircraft improvements, performance improvement and cost reduction through mass production. Another notable characteristic of these programs are that related information is announced openly, and that technology transfer from the military to the civilian sector is accomplished in a positive way.

(1) Program for Design & Manufacture of Low-Cost Composites (DMLCC)

Boeing, MDC, GE and Bell Helicopter-Textron have jointly concluded a contract to implement a research project to commercialize a mass production model of the F-22 with a budget of $50 million by 1997. The target is a 50% cost reduction compared with the budget to develop structures consisting of conventional types of composite materials. The development of a forming and assembling concept based on the concurrent engineering approach is in progress and verification is proceeding with a real model.

(2) Advanced Fuselage Structure (AFS) Program

Research is in progress for a 20% weight reduction and a 30% cost down with the target focussed on the integral wing/fuselage of the Navy's F/A-18E/F fighter plane, with a budget of $30 million over a three-year period. The targets are the development and commercialization of long discontinuous fiber (LDF) prepreg made of thermoplastic resin.

(3) Low-Cost Composite Processing (LCCP) Program

Research on a low-cost process for the manufacture of diverse products in small lots or for manufacturing parts of experimentally fabricated planes has the objective of suppressing recurring costs in small-scale manufacture. As the method of approach for cost reduction, low-cost jigs based on direct use of gypsum are used, and autoclaves disused.

(4) Advanced Composite Technology (ACT) Program

This is a program to develop practical technologies under NASA's 10-year program, and is a large-scale project advanced jointly by the industrial, academical and governmental sectors to develop materials, conduct structural analysis and establish innovative design and manufacturing technologies. Results are presented jointly by information exchange through conferences held every other year. In particular, the central themes are the development of advanced designing and manufacture of passenger planes, material research and structural analysis, and a high target is set of reducing the cost of metallic structures by as much as 25% compared with before.

(5) Advanced Technology Composite Aircraft Structure (ATCAS) Program

NASA, separate from ACT, is implementing an ATCAS program with the objective of developing lightweight, low-cost composite structures for use in structuring the bodies of wide-body commercial planes. In this program, Boeing, as a result of studies on applying composite structures to crown panels, has announced that weight reduction by 50% and cost reduction of 25% can be anticipated by optimizing the designing and fabrication methods. MDC is meanwhile studying the case of using composite materials in the primary structures of civilian STOL planes, the weight has been reduced, and the direct operating cost and investment profit increased, but the repair cost and the fabrication cost would be increased.

Trends in Aircraft Composite Material Technologies and Outlook on Smart Composite Structure

1.2. Present Development of Low-Cost Composite Material Technologies[1]

Fig. 1 shows the present and future estimates for the price trends of composite airframe prices in comparison with metallic structures. The existing prices of metal structures is $150-300/lb, compared with that of composite material structures of $350-500/lb. In the 21st century, the price is estimated to be reduced to $100-250/lb. This assumes the cost reduction of 25% that is the target of the ATS program.

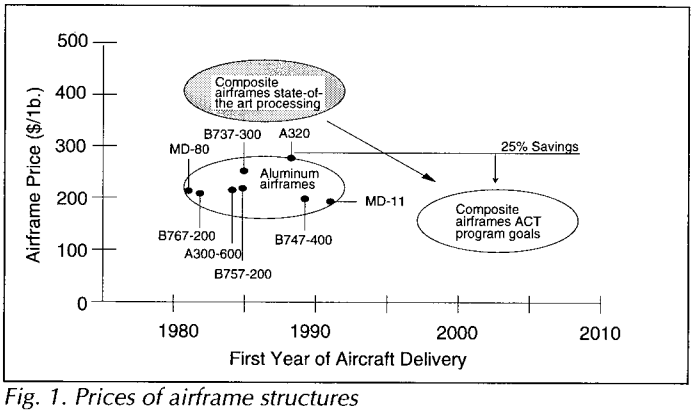

Fig. 1. Prices of airframe structures

Fig. 2 shows the cost breakdown of the composite wing by the ACT program. The material cost is about 20%, the fabrication cost 25%, and major and minor assembly costs 40%, and other design tooling and planning costs 15%. For drastic target cost reduction, it will be necessary to achieve cost reduction on all constituent elements, in particular, fabrication and assembling.

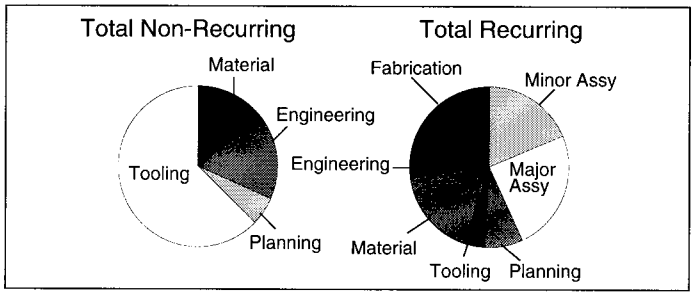

Fig. 2. Cost breakdown of composite wing

(1) Cost Reduction of Materials

In general, the costs of aerospace materials are much higher than for civilian materials, and with composite materials, in particular, the costs are incomparably higher. The primary reason is the stringent performance and quality demands for the materials in order to secure aircraft safety and reliability. Also, numerous tests are necessary to set the allowable design values, which has to be added on to all these material costs.

Further, with composite materials, no public metallic material specification are being enforced, so each user enterprise is conducting qualification tests and design tolerance value acquisition tests in conformance with its own specifications. The MIL-HDBK-17 in the United States provide the guidelines for the acquisition of characteristic data and analysis of composite materials, the guidelines for acquiring characteristic data for material approval, the procedures for evaluating constituent material for composite materials and laminates, the procedures for analyzing the detailed parts of composite material structures, and the method of standardization on the basis of statistical methods. With this as the basis, the establishment of standards and design data bases is expected to proceed for material qualification, material approval and design tolerance value setting tests.

Regarding material development, the wet process such as the resin transfer molding (RTM) process has attracted attention recently that uses dry preforms as the interim material, so research is being advanced intensively to establish weaving technologies to manufacture preforms. Also, thermoplastic composite materials are being reassessed due to the development of new intermediate materials such as resin powder coated fibers.

(2) Cost Reduction of Fabrication Technologies

As pointed out earlier, the reduction of fabricating and assembling costs is the major issue, and at present, manufacturing technology development may be divided into the following five directions.

1) Improvement and efficiency improvement of conventional methods relating primarily to thermosetting resin-based composite materials: automation technologies such as filament winding, pulltrusion, blading, towplacement, automatic nesting, laser template, etc.

2) Wet process technologies: processes such as RTM and resin film infusion (RFI) processes to impregnate dry preforms with resin in liquid phase state.

3) Development of new intermediate materials for easy fabrication of thermoplastic resin-based composite materials and in-situ fabrication process: Commingled yarn, resin powder coated towpreg, direct consolidation and other new fabrication processes.

4) Autoclave-alienated curing technology: non-heated curing and fabrication processes using microwaves, electron beams/X-rays, ultrasonic waves and other high-energy resources.

5) Simulation technologies: Modeling/simulation technologies for lamination, impregnation, molding and curing processes, including effective utilization of CAD/CAM .

From the aspects of environmental compatibility, strong demands are being placed on the development of fabrication processes generating minimal wastes in the manufacturing process, fabrication using no harmful chemical substance or organic solvent and

technologies for the recycling of composite materials, and the critical issue consists of how to strike a balance between these technologies and cost reduction. In this connection, the thermoplastic resin-based composite materials feature more desirable characteristics than thermosetting resin-based composite materials.

(3) Low-Cost Designing Technologies

The cost of airframe structures relies largely on the stage of design to determine the materials, structural concepts and method of conducting inspections, so design is vital in cost reduction. In the diverse programs described earlier, various innovative structural concepts are being identified which may bring about big changes in conventional concepts. Therefore, a major issue is to develop structural concepts which are compatible with new low-cost fabrication processes, and in this connection with design optimization, research is in progress to establish design procedures which involve the cost function in addition to considerations of weight as in the past.

In the concurrent engineering approach, diverse related sectors are involved from the stage of designing that is advanced with manufacturing in mind, and efforts being made for cost reduction while satisfying structural performance and quality requirements. In Japan, it will be necessary to achieve cost reduction in manufacturing not by applying new concepts but by utilizing the computer networks which have been applied before. Incidentally, it is only natural that the establishment of specification standardization and cost reduction are vital factors.

(4) Establishment of Maintenance and Repair Technologies for Cost Reduction

The biggest concern of airlines in connection with composite materials is the difficulty of conducting inspections and repairs. Also, more recently, in concert with the increasing servicing of aged-aircraft, the need is being raised to improve inspection and repair technologies for securing safety. Inspection methods, in addition to the conventional methods, include the ultrasonic array method, the laser radiation ultrasonic method, the laser holography method and the optical interference fringe inspection method. In particular, technical innovation is rapidly proceeding in the sector of image processing, but much still remains to be achieved in the aspects of establishing simple practical technologies.

For reduction in the life cycle costs of commercial transports, cost reduction will be indispensable in connection with the maintenance, inspection and repair of composite material structures, also simplification and speed-up in all phases of maintenance and inspections. Efficiency improvement is strongly required by airlines from techniques for the evaluation, removal and repair of damaged composite materials.

To reduce repair costs, a Commercial Aircraft Composite Repair Committee (CACRC) has been established under the leadership of the International Air Transport Association (IATA), the Air Transport Association of America (ATA) and the Society of Automotive Engineering (SAE), and with the participation of aircraft manufacturers, airlines and material manufacturers, and is engaged in activities to establish standard methods to repair composite material components.

2. R&D of Smart Structure System[3][4]

The concept of "structures" had consisted of the passive and fixed concept of primarily maintaining the strength and rigidity. However, more recently, smart functional materials or active materials featuring sensor functions or actuator functions have become included and integrated into these artificial structures, with the result that sophisticated composite structures have emerged with functions such as intelligence, judgement and response like a living body, or structures which feature the functions of sensing structural integrity or external disturbances and cope with these situations appropriately.

This concept emerged when the late Shoji Shimamura of the Mechanical Engineering Laboratory of the Agency of Industrial Science and Technology proposed in 1978 for the world's first time a concept of materials which change their characteristics appropriately in conformance with external stimulations (intelligent materials) (see Fig. 3). However, the commercialization of the technology to incorporate intelligent functions into materials and structures was realized only after the establishment of

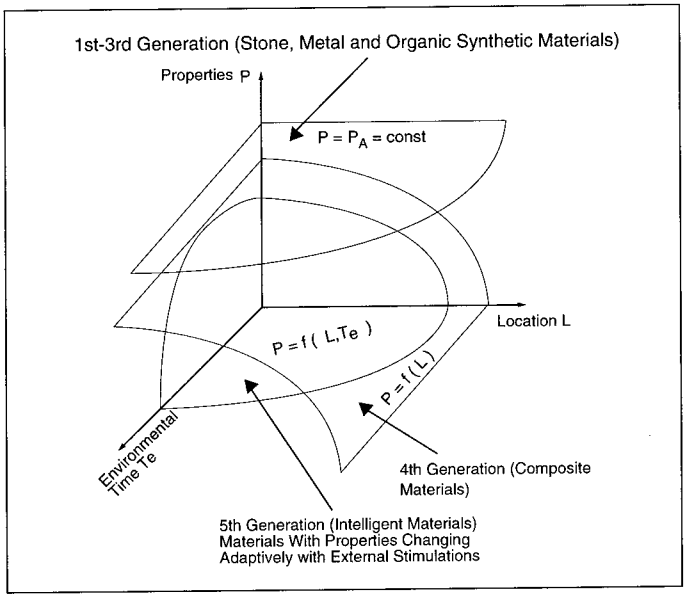

Fig. 3. Characteristics of materials of various generations (Shoji Shimamura, 1978)

Trends in Aircraft Composite Material Technologies and Outlook on Smart Composite Structure

material technologies relating to optical fiber, piezoelectric materials and shape memory alloys as well as the establishment of information processing and control logics technologies.

In 1988, Professor Miura of the Institute of Space and Astronautical Science proposed the "adaptive structure," and in 1989, Council for Aeronautics, Electronics and Other Advanced Technologies of the Science and Technology Agency announced its Report No. 13 on "The Concept of Intelligent of Materials and Guidelines or Their R & D Promotion," and Japan took a leading international role in this sector. More recently, western countries which directed their attention on this advanced technology are implementing related R & D projects intensively as national projects (the EU Project in Europe).

This technology is applicable to structural systems consisting of all types of metal, ceramic and composite materials, among which composite materials, in particular, incorporate active materials featuring sensor and actuator functions in the aspects of material constitute and manufacturing processes, and may be regarded as intrinsically adaptable to the realization of the so-called "smart structural systems" incorporated with active adaptive functions. When using composite materials as the host structural materials, these composite materials are called "smart composites," point in the direction of progress as next-generation composite structures (see Fig. 4) and are anticipated to serve as a technology holding great possibilities of simultaneously enabling reliability improvement and cost reduction.

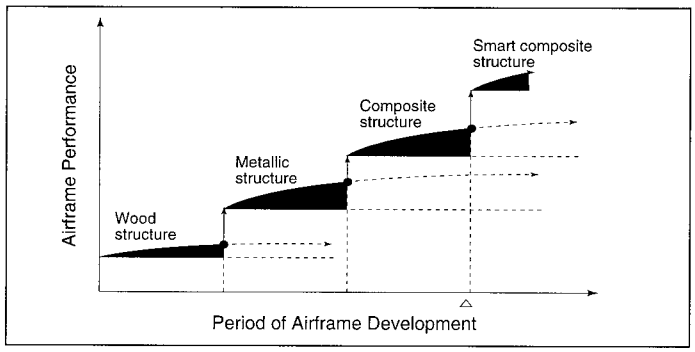

Fig. 4. Transition in airframe structures (W. Schmidt, C. Boller (DASA), 1994)

2.1. Basic Concept of Smart Structural Systems

Fig. 5 shows the basic concept of the smart structural system. In the smart structural system, the host structure incorporates the sensor (nerve) and actuator element (muscles) in coordinated integration as in a living body, so the structure, by merit of its controller with learning/judgement function, is capable of monitoring and repairing (health monitoring/care) its own soundness, and capable of suppressing vibrations and controlling its shape actively with respect to external disturbances. Ultimately, the host structure will also incorporate an element for controlling the learning/judgement functions.

What can smart structural systems do? More specifically, the following functions are conceivable.

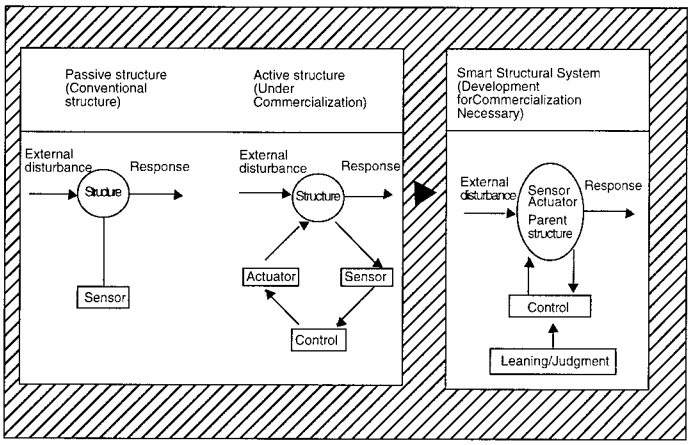

Fig. 5. Basic concepts of conventional and intelligent structural systems

(1) Structural Health Monitoring/Care

* Improvement of structure reliability and safety: Reduction of life cycle cost due to structural soundness monitoring, assurance, residual life estimation and the reduction of regular inspections from "the cradle to the grave" or in all processes from structure designing, manufacture, quality assurance, operation, repair, to recycling and disposal.
* Automatic integration of load and environmental data at time of use to acquire residual life estimation and design data.
* Optimization, quality improvement and cost reduction of processes by incorporating smartness (in-process monitoring) in the process of composite fabrication.
* Self-repair.

(2) Active Control of Structures

* Improvement of service life and agreeableness by improving the adaptability of vibration and noise suppression structures.
* Optimization of load position through shape control (improvement of structural stability), active control of fluid dynamic surface shape, and improvement of motional property and energy consumption efficiency through vibration and noise suppression.

(3) Simplification and Weight Reduction of Structural Systems

* Simplification and slimming of control systems by integrating intelligent functional materials together with host structures.

2.2. Themes in R&D of Smart Materials and Structural Systems

Fig. 6 shows the R&D themes which have to be resolved for the realization of smart structural systems, their correlations and effects.

(1) Smart Functional Materials

Sensing and actuation are vital in order to incorporate structures with the intelligence function, and the key technologies for the manifestation of this function are the technologies for improving the properties of these so-called smart functional materials and for providing them with the necessary shapes, which enable these functional materials to be unitized with their host structures without any irregularity.

There is as yet no universal sensor that is usable as the core element for the health monitoring of structures, but the optical fiber sensor features excellent environmental compatibility with electromagnetic waves, temperature and moisture, in principle enables multi-point sensing with a single optical fiber cable, and is therefore attracting the greatest attention.

Present optical fibers have large diameters (250 μm) and cannot be incorporated into parent structures with ease, so to cope with these problems, it will be necessary to develop an optical fiber of smaller diameter (less than 50 μm) capable of resisting deterioration. Also requiring development is a technology for the precision machining of sensors (grating) to enable these sensors to be used in combination with fine-diameter fibers, and the development of a surface improvement technology to improve the physical, chemical and mechanical compatibilities of optical fibers with their host structures.

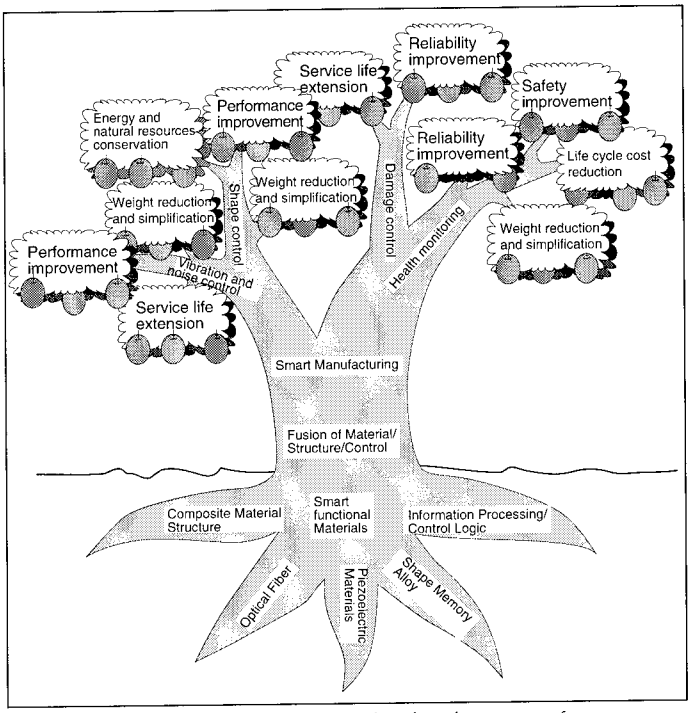

Fig. 6. Correlation of R&D themes for development of smart structural systems

Actuator materials are vital in active controls by way of suppressing the vibrations and noises and changing the shapes of structures. Fig. 6 shows candidate actuator materials such as piezoelectric ceramics and shape memory alloys, but there are other materials such as electrostrictive materials, magnetostrictive materials and electro-rheological fluids. Piezoelectric materials, magnetostrictive materials and shape memory alloys, by utilizing their material bidirectional characteristics, enable the manifestation of sensory actuator properties in their use, or of displaying the functions of both sensor and actuator.

The piezoelectric ceramic needs to have more excellent displacement and higher power. The desires of users are to have the displacement increased from the present 0.1% to 0.5%, and the strength increased from 100 MPa to 200 MPa. Another desire is to have the material produced in fiber and foil form to enable integrated use with host structures.

The shape memory alloy features great strength in addition to displaying an excellent shape recovery force and high displacement, and is therefore usable conveniently as an acutator material. Further improvement of its strength and recovery attribute will be necessary to enable application to intelligent structural systems, or its strength will have to be increased by 1.5 times compared with the existing TiNi material, its recovery force improved by 2 times and its fatigue deterioration (memory loss) suppressed further. This material recovers its shape by phase transformation, so a fast response cannot be anticipated compared with piezoelectric and magnetostrictive materials. To attain a fast response, the development of thin film and fine wire manufacturing technologies will be indispensable.

(2) Smart Manufacturing

This is the manufacture of smart structures whose host structures consist primarily of composite materials, and the process of incorporating these materials with the smart function. Closest to establishment is a technology for embedding a sensor in the precured composite material, then monitoring the soundness of material and structure from the stage of fabrication through operation to disposal.

This is technology to optimize the fabrication conditions, shorten the curing time, reduce fabrication cost and improve product quality by monitoring on-line the process temperature, pressure and matrix resin viscosity, curning and other physical and chemical reactions. Many technical matters remain to be resolved in connection with the multi constant and multi point sensing tech-

Trends in Aircraft Composite Material Technologies and Outlook on Smart Composite Structure

nique generated through optical fiber, sensor/actuator embedding technology, and the development of performed materials matched to these technologies.

The technologies lying on the projection line of fabrication by conventional autoclave processing may not provide the anticipated results, so the electron beam / X-ray curing and the RTM process as wet process will become effective. These fabrication technologies are highly promising processes for composite fabrication at low cost as described earlier, so process optimization and further cost reduction are anticipated through in-process monitoring.

(3) Health Monitoring and Damage Control Technologies

Research relating to structure health monitoring was initiated after the Aloha Airways Boeing 737 accident on April 28, 1988, with the objective of proposing techniques to prevent similar accidents. Sensors similar to the nerves of the human being are incorporated in an aircraft body to constantly monitor the soundness of aircraft structures during flights, and a system was proposed that even includes will determination by introducing artificial intelligence. In this case, the optical fiber sensor system was evaluated as a promising sensor system.

This system enables the "living experience" encountered during aircraft operation to be monitored constantly with the artificial nerves incorporated in structural members, or with the optical fiber continuous sensor network, by which the external and internal environmental influences exerted on the soundness and conditions of the structures are learned. In addition, the structures regain youthfulness at appropriate periods of their lifetime and so prolong service lives through repairs up to the time of ultimate disposal, without undergoing any critical failure. Therefore, the structure designer does not learn from structural destruction accidents as in the past but can rather acquire learning from the structure's "history during its existence," which represents a new design thought and an innovative concept for securing the soundness and safety of aircraft structures.

The optical fiber sensor is highly advantageous for detecting internal damage such as delamination that is characteristic of composite materials, also usable for quality control in the process of manufacturing as pointed out earlier. For the commercialization of this technology, it will be necessary to establish technologies for measuring the temperatures and strains by optical fiber sensors, for the simultaneous multi-point measuring, for the optimum distribution of sensor networks, and for the identification of the types, positions and sizes of damages. Also necessary is the establishment of a system for self-diagnosis of the safety limits and the residual service lives of structures from the information transmitted by sensors. Also proposed was an active damage control concept that is designed to utilize health monitoring information and which is designed to suppress the advancement of cracks and delamination as well as to prolong the service lives of these structures by utilizing the functions of actuators such as shape memory alloys incorporated in the aircraft structure during the fabrication process.

Fig. 7 shows the principle of life cycle cost reduction based on health monitoring and smart manufacturing.

(4) Vibration and Noise Control Technology

The conventional method of controlling the vibrations of structures consisted of attenuation by fitting shaker on the structures. Therefore, the size of the force to suppress vibrations was gov-

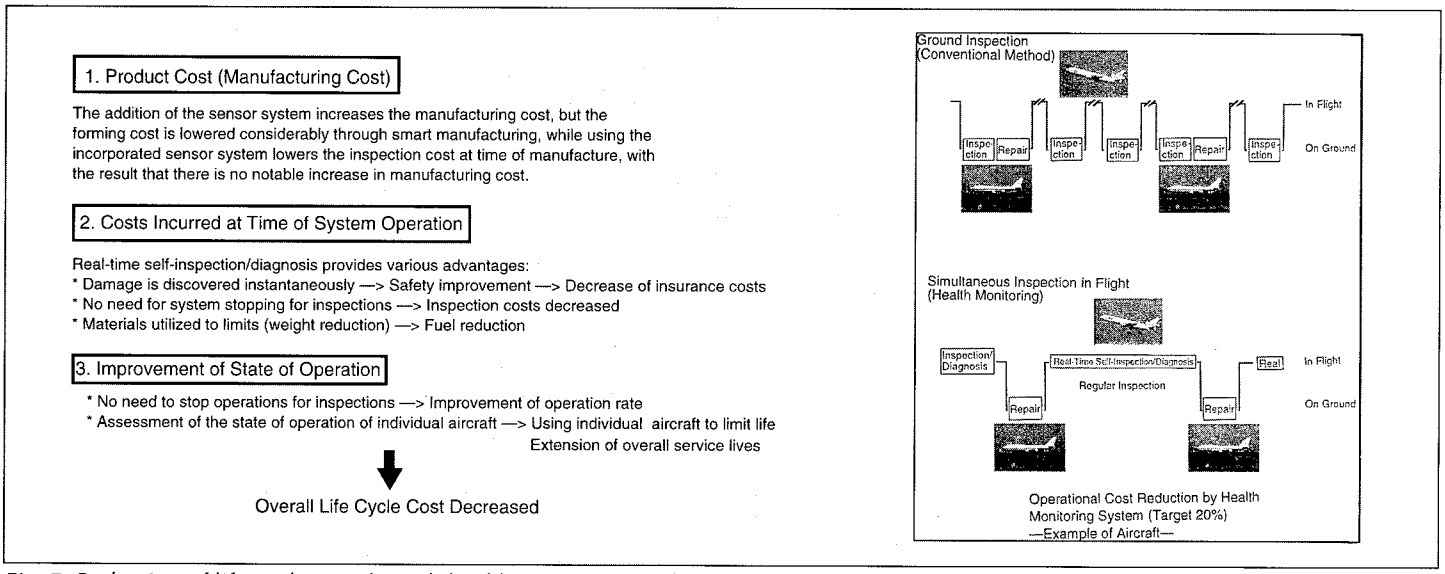

Fig. 7. Reduction of life cycle cost through health monitoring and smart manufacturing

:rned by the shaker weight. In this respect, the actuators arranged ike muscles on the structures can be made very light compared vith ordinary shakers and capable of displaying a large vibration ıttenuation effect by weight ratio.

To commercialize this vibration control technology, it has been ıecessary to improve the performance of the aforementioned ac- uator material, also to establish technologies to simultaneously)ptimize and integrate the designs of the host structures, sensors ınd actuators, and to establish a technology to fabricate related :onstituents in an integrated assembly.

(5) Shape Control Technology

As a typical example of conventional shape control method, there is the shape control of aircraft wing. Movable parts, such as struts and flaps are controlled for adaptation to the flying environment with hydraulic actuators. Smart structural systems do not have such movable joint parts and the structures themselves assume appropriate shapes to adapt themselves to the environmental conditions. Internally distributed system actuators consisting of piezoelectric materials, shape memory alloys, electrostrictive and magnetostrictive materials are used to developed a flexible shape variable structural system.

Already, basic research is in progress to control aircraft wings. Shape memory alloys are used at the parts of large deformation, and piezoelectric ceramics at the parts of feeble deformation to fabricate an experimental real aircraft scale model, and the improved aerodynamic performance and the vibration suppression effect verified through wind tunnel tests.[5]

This technology, in addition to its application to aircraft wing shape control, is anticipated in application to helicopter rotary blades, fan blades of turbine engines and wind power generation windmills to improve performance, decrease vibrations and noise, and for the suppression of fatigue fracture. For technology commercialization, technical breakthroughs will be necessary in the same areas as with vibration control technology, and many other themes remain to be resolved in the materials as well as with structure design in order to commercialize the technology into a flexible structural system.

3. Future Outlook on the Smart Structural System

The smart structural system concept was proposed at an early stage, the concept is clear, and research has been conducted intensively with definite application targets in Western countries. Despite this situation, why is it that there is hardly any example of commercialization? The reason is that this technology essentially constitutes the integration of technologies relating to materials, structures, controls and information processing, and for its realization it will be necessary to develop design and control technologies which simultaneously optimize structures and control functions, to develop smart functional materials and to establish technologies for the integrated fusion of processes including the technology to form composite structures.

In Western countries, starting from the proposal of the applications concept and proceeding from the stage of the concept mathematical modeling to the verification of model supplies, it is now the stage in which various large-scale national projects are being advanced (in the U.S. the Smart Wind Program and in the EU the Monitor Project). Also, the supersonic transport (SST) that is representative of futuristic aircraft will reportedly be fabricated with composite material structures, and the smart structural system is recognized as a key technology for the realization of SST. Accordingly, there is a critical need to advance research to develop technologies to reduce noise in passenger cabins, prevent acoustic fatigue near engines, conduct health monitoring of structures, measure aging behaviors through long-term heating of composite materials, integrate structures and antenna, and suppress flutter.[6]

In Japan, there is a move to implement these projects, while the holding of international academic conferences in the country is increasing from year to year, and more domestic researchers are active in this interdisciplinary domain. These technologies lie in the domains in which Japan has continued to assume a pioneering role, so great expectations are placed on the early commencement of these R&D projects, and on the commercialization of a futuristic aircraft applying Japan's unique smart composite materials and structural technologies.

This article was compiled on the basis of the research survey reports described in references (1), (3) and (4). The writer offers his sincerest gratitude to the chairmen of these committees who offered their kind cooperation, as well as to the members of these committees.

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NEW TECHNOLOGY & PRODUCTS

This section provides information about recently developed technologies and products, divided into Advanced Materials, Electronics & Optics, Information & Communications, Process & Production Engineering, Construction & Transportation, Energy, Environment, and Biotechnology & Medical Science.

Advanced Materials

97-12-001-01
Antibacterial Grade Transparent Polystyrene

Japan Polystyrene INC has developed a transparent polystyrene (PS) material JPS G757XW featuring antibacterial properties which is safe in use.

In general, transparent polystyrene (GPPS) with added inorganic antibacterial agent becomes cloudy and loses its transparency. The company elucidated the mechanism by which the material retains its transparency even when inorganic antibacterial agent is added, and succeeded in developing a transparent polystyrene material of antibacterial grade featuring excellent antibacterial properties. Patents are pending on a technology to use antibacterial agents in the process of manufacturing polystyrene.

Methods to check the antibacterial properties of materials include the film adherence method in which a fluid containing bacteria is dripped on the material surface, a film adhered tightly on the surface, then retained in this state for 24 hrs at 25 °C and the number of residual bacteria measured. Tests with this method corroborated that over 99% of E. coli and staphylococcus are eliminated. With antibacterial plastics, the general method is to add an antibacterial agent in a later process of manufacture, in which case deterioration of plastic properties and color change are inevitable. To resolve these problems, the company improved the manufacturing process to enable antibacterial agents to be added directly in the intermediate stage of polystyrene manufacture, by which the later process is eliminated and also enables product cost reduction.

To produce this grade of polystyrene, a high molecular weight GPPS is used and a technology developed by the company applied to incorporate the material with great hardness, so that the material features an enormous strength comparable to that of AS plastics, as corroborated through ball dropping impact tests. The material is already being used to manufacture transparent trays, bottle racks, egg cases and other products used inside refrigerators, and the company anticipates the application to the manufacture of stationery, home implements, tools and other products for which antibacterial versions are required. For further details relating to this product, please place inquiries to Japan Polystyrene INC.

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97-12-001-02
Aluminum Material Pressable Without Use of Lubricant

Kobe Steel, Ltd. has developed a new type of corrosion-resistant precoated aluminum material KS701 that can be pressed intact without using lubricating oil.

Conventional types of aluminum sheets are coated with lubricating oil to prevent damage on the sheet surface. The lubricating oil is needed for the pressing process of aluminum sheets, and since the sheets have to be washed after being pressed, the processing cost is increased and there is also the problem of having to treat the waste water. The new material eliminates this intermediate process in addition to reducing the inpact on the environment. The aluminum sheet is available at a cost that is 20-30% higher than ordinary sheets.

KS701 has a coating of a chromium phosphate film and a high-strength resin of high ductility with a thickness of μm, which provides the sheet surface with adequate smoothness and hardness. Specifically, the frictional coefficient of 0.12 of an untreated sheet is halved to 0.06, and the surface hardness in pencil hardness is increased from 2 H to 5 H, which eliminates the need for coating the surface with a lubricant for pressworking.

Kobe Steel possesses thin film coating technology through its manufacture of aluminum beer cans, which was applied to develop the new sheet coating technology. The new aluminum sheet is applicable to the manufacture of floppy disks, minidisks, home electrical appliances and automotive parts. The company has already started distributing samples of the aluminum sheet to manufacturers. Compared with conventional types of metal sheets such as stainless steel, the aluminum sheet enables product weights to be decreased to one-half.

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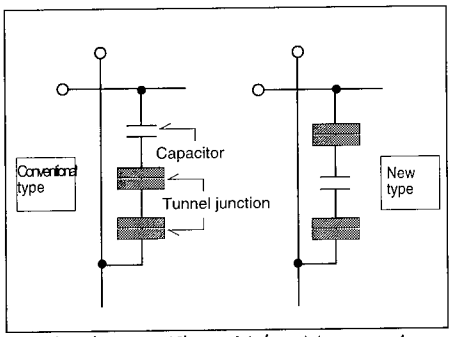
Electronics & Optics

97-12-002-01
Single-Electron Three-Value Memory Array

Assoc. Prof. Y. Suda and a research team of the Tokyo University of Agriculture and Technology have developed a single-electron, three-value memory array featuring a new control technique in which the three values of 0, 1 and 2 are controlled by a single electron.

With this new control technique, the memory cell that is the basic unit of the memory device has a special type of construction. A capacitor capable of storing electrons is sandwiched between a pair of insulating elements called a tunnel junction which enables electron passage freely, by which information can be memorized in three values. Specifically, the memory array can assume three states, one electron on the capacitor upper side, and a hole on the underside, one electron on the underside of the capacitor, and a hole on the upper side, and neither electron nor hole on either side.



Single-Electron Three-Value Memory Array

Simulation tests were conducted by assuming a source voltage of 10 V. There were four types of voltages by which information can be stored or retrieved, indicating that the array is usable as a memory. Ordinary types of memory devices store information in the form of 0 or 1 with respect to two voltages, but the new memory features an arithmetic function as the information inside the memory cell is changed when a specific voltage is impressed. By fabricating a data processing circuit in the periphery of a memory displaying this characteristic, it will be possible to commercialize a new type of ultrahigh-speed integrated circuit.

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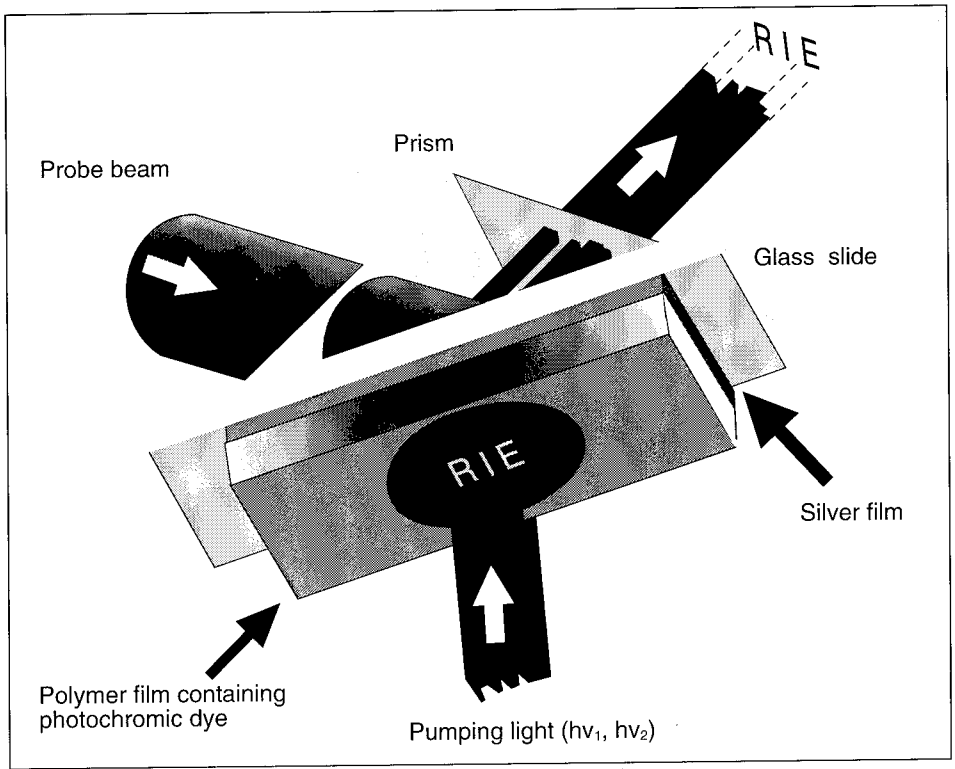
97-12-002-02
Ultrafast All-Optical Switch

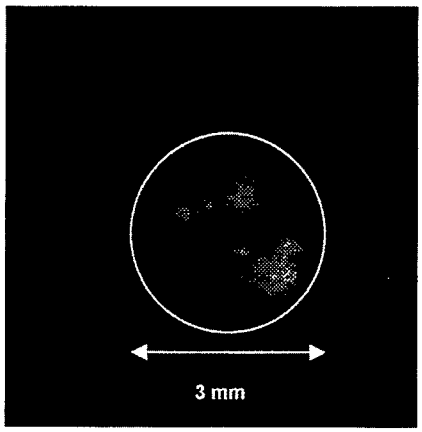
Prof. T. Nagamura and his research team of the Research Institute of Electronics and the Graduate School of Electronic Science and Technology, Shizuoka University, have changed the complex refractive index of waveguide structure thin films by optical reaction and switched ON/OFF a beam of light in parallel with a separate beam of light. They devised an ultrahigh-speed parallel all-optical switch that can retain these states without consuming any power, and by using a prototype switching device, conducted tests which corroborated the nanosec ON/OFF response and image recording capability.

Fig. shows the construction of the central part of the new all-optical switch. Silver is vacuum vapor deposited on a slide glass to a thickness of several dozen nanometers, over which is formed a polymer film of several hundred nanometers containing a photochromic pigment that changes its color in conformance with the light response. When the readout light is irradiated on a prism in this state, the light is normally reflected by over 90%. On the other hand, with a specific angle of incidence, a waveguide mode is obtained in which the light reflection becomes very slight and less than a few per cent. This resonance condition is determined by several parameters, one of which is the polymer film refractive index. This is a complex quantity and the resonance angle swerves from left to right when the real value part is changed, and when the imaginary value part is increased, the reflectance is increased with the same resonance angle. This mechanism is utilized as an optical switch.

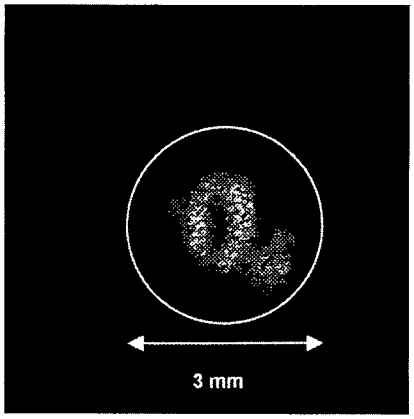
In experiments, an ultraviolet/visible laser beam was irradiated as an ON/OFF write-in light beam on a photochromic pigment known as spiropyran, by which the polymer film complex refractive index was changed in concert with a change in the pig-



Construction of the central part of the new all-optical switch



(a) Before excitation



(b) After excitation

ment color. When the reflection ratio was set at its minimum angle and a blue laser beam irradiated, the reflection ratio with the same nanosec pulse width was increased by over 10 times to permit switch ON. As shown in Fig. 2, it is possible to instantaneously record two-dimensional information on a separate light beam as a positive image, and this state can be retained without any power. Switch OFF is possible by irradiating red light, in which case a nanosec response was also confirmed.

The signal intensities at ON/OFF are basically determined by the write-in light intensity and the quantum yield of optical response. Several types of photochromic pigments featuring high efficiencies and excellent repetitive durabilities have been developed recently, so this new system is conceived to be applicable to the creation of two-dimensional cache memories and parallel optical switches. By utilizing the complex refractive index change based on organic pigment optical excitation by a similar optical device developed by the same research team last year, it will be possible in principle to apply this ultrafast all-optical switch to ultrahigh-speed data processing systems together with spatial optical modulation with a response characteristic of over GHz level.

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97-12-002-03
CCD Camera Module Series for Personal Computer Video Conference Systems

Sanyo Electric Co., Ltd. has developed a charge-coupled device (CCD) camera module that is optimized for application as a video conference system using personal computers. This CCD camera module is designed for use with the video telephones and video conference systems using personal computer networks which are coming into rapid use primarily in the U.S.

The new CCD camera module SIS4000 Series employs a high-performance CCD the company developed for use with digital cameras, and incorporates a function to process dynamic images to enable the transmission of quality conference system images. These camera modules incorporate functions to work with three types of personal computer interfaces, the PCMCIA, USB and parallel ports, and are designed to enable camera set manufacturers to venture into mass production readily.

Developed and marketed at the same time was an SIS5000 Series camera modules such as M.261 and H.263 incorporating image compression functions. The domestic sampling prices are ¥30,000 each for the 4000 Series versions, and ¥60,000 each for the 5000 Series versions.

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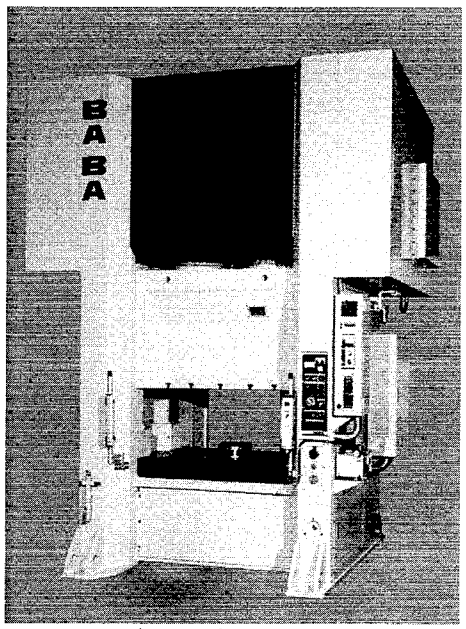
Machinery & Mechatronics

97-12-003-01
200-Ton Link Press for Precision Machining

Baba Iron Works Co., Ltd., by automatically controlling the die contact speed, has developed a 200-t capacity link motion press 200 Ton, 2-Point Press that performs various types of precision machining including fine blanking.

This is a straight side type equipped with a highly rigid frame on both left and right sides. It mounts a unique type of connecting rod, by which the speed of descent of the slide from the upper dead point to directly in front of the die as well as the speed of raising the slide from its lower dead point to the upper dead point have been increased, or a link mechanism is introduced of retarding the speed of only the part coming into contact with the die.

As a result, there are minimal shocks to the die and workpiece, and a wide range of presswork can be performed very accurately while making the wall



200-Ton Link Press for Precision Machining

thicknesses of the workpieces uniform. The torque capacity is high, or 1.5-1.6 times the crank ratio, and the use of a highly rigid frame enables deep draw machining. De-

spite its large weight of 200 t, it can perform heavy-duty stamping of workpieces with a thickness of 10 mm, and cold and hot forging is also possible. In addition, the introduction of a quick return mechanism achieves a productivity that is 20-30% higher than that of a crank press. Further, a special type of rubber and a noise absorbing material are used in the casing, by which noise and vibration, the two major problems normally associated with presses, are suppressed substantially. The material feed system is numerically controlled.

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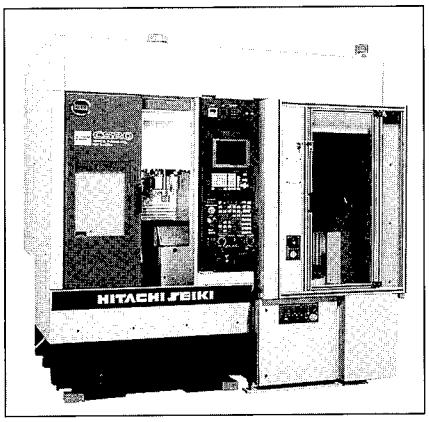
97-12-003-02
New High-Speed Numerically Controlled Turning Cell

Hitachi Seiki Co., Ltd. has developed a vertical numerically controlled (NC) lathe (turning cell) CS 20 with a machining speed 20% faster compared with its conventional counterparts. The number of parts has been decreased considerably for a price reduction of about 40%, and the operations of workpiece fitting, releasing and transfer are all accomplished automatically.

CS 20 is an NC lathe designed with completely automated functions, which eliminates the need for a special-purpose robot or transfer mechanism, by which drastic cost



NC turning cell CS20

reduction has been achieved. The spindle speed has a wide range of 30-5,000 rpm and can be changed flexibly in conformance with the size and shape of the workpiece. Up to 12 cutting tools are mounted on the turret to perform high-speed, accurate machining. Once lubricated, it performs its tasks with stability without requiring relubrication for a life time, and maintenance is accomplished with ease.

The lathe has a breadth of 2,575 mm, depth of 2,075 mm, height of 2,450 mm and weighs 4,900 kg. It is sold at a domestic price of ¥11,500,000, much lower than the price of conventional comparable lathes.

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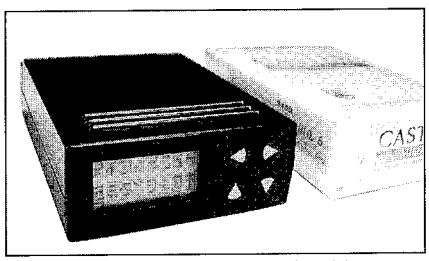
Information & Communications

97-12-004-01
Data Storage System Requiring No Power Unit

System Design Co., Ltd. has developed a data storage system that requires no power unit whatsoever. This data storage system is used in linkage with the interface RS232C that is in wide use, and its applications include use to input machining programs in linkage with an NC machine tool, long-term retrieval of data, and collation of sales information in linkage with a point-of-sale cash register.

The internal control circuit power is derived from the RS232C interface with a high-efficiency power conversion circuit developed by the company. The internal control circuit is designed for thorough power conservation, the system is the first of its kind in the world, and patents are pending for the system.


Data Storage System Requiring No Power Unit

The system uses a flash memory that requires no backup with a battery, and data can be retained semi-permanently. Without any mechanical mechanism, it retains stored data with extremely high reliability even if there are magnets or static electricity in its proximity. The system is available in the three storage capacities of 1 M, 2 M and 3 M, and is sold at a domestic price from ¥59,800 to ¥99,800, depending on its specifications.

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97-12-004-02
1.4 million pixels Digital Camera

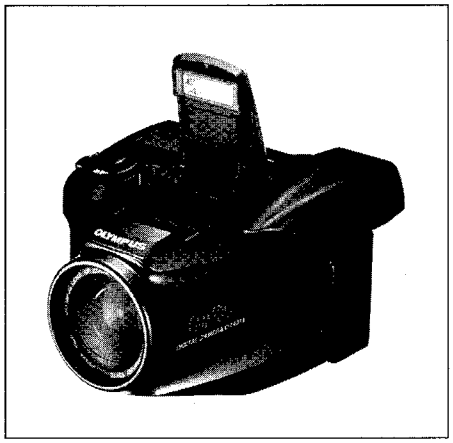
Olympus Optical Co., Ltd. is developed the new CAMEDIA C-1400L and C-1000L Digital Cameras. The new models deliver image quality on a level with silver-halide photography. The keys to this achievement are a super-high-resolution progressive CCD and a high-performance 3×optical zoom lens. The C-1400L has 1.4 million pixels, while the C-1000L has 850,000 pixels.

Both models also feature the advanced functions of an SLR camera, including a TTL optical viewfinder, spot metering and exposure compensation. Images are recorded on a removable 3.3V SmartMedia card, so storage is unlimited and the interface is versatile. Their much applauded 1.8-inch TFT color LCD monitor simplifies checking a shot immediately.

The C-1400L has a 2/3-inch super-high-resolution progressive CCD with 1.4 million pixels. Offering a new degree of precision, it features unparalleled SXGA image quality — the highest achieved in an affordable digital camera. With its 1/2-inch progressive CCD and 850,000 pixels, the C-1000L delivers the best image quality available in the XGA class. To maximize this performance, an original Olympus algorithm optimizes resolution and color reproduction.

To raise image quality to the level of silver-halide photography, a digital lens must make the most of a mega-pixel CCD sensitivity. Drawing on its long experience in developing and manufacturing 35 mm cameras, Olympus has achieved this feat with the new C-1400L and C-1000L.

Both models have a bright F2.8-3.9 optical 3× zoom lens with a range of 9.2-28 mm. Designed with the most advanced optical technologies, they have more than 100 lines/mm at the center — higher resolution than even SLR lenses generally offer. The seven high-performance glass lens elements, including one aspherical element, ensure sharp images to the edge of the CCD. And even with its sophisticated capabilities, the lens is just as compact as the one on earlier models since both zooming and focusing are handled by an internal system.



CAMEDIA C-1400L

The new cameras weigh only 470 grams, and they measure 115(W) × 83(H) × 130(D) mm. The trim lines and low weight make it easy to take them along. Price; C-1400L: ¥128,000. C-1000L:¥99,800.

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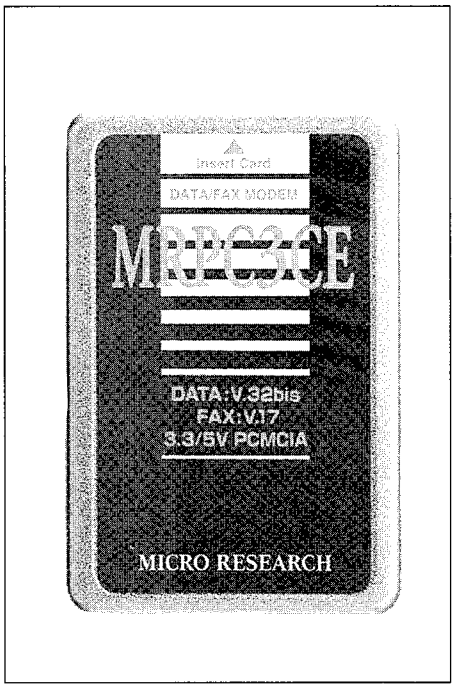
97-12-004-03
PC Card Type FAX Modem With Double Battery Life

Micro Research Laboratory, Inc. has developed a card type modem Micro Research MRPC3CE featuring minimal power consumption. Compared with the company's existing products, the new modem enables battery service lives to be doubled, making the modem ideal for use by salesmen who carry personal computers on their business itineraries.

The new modem has a communications speed of 14.4 kb/s, which is low by the standards of present modems, but there is no inconvenience in transmitting electronic mail. Conventional notebook type personal computers operate PC cards at a voltage of 5 V, but the recent trend is the increasing use of modems working at 3.3 V for power saving. The company redesigned the modem circuits to enable the modem to be worked at either 5 V or 3.3 V.



PC Card Type FAX Modem With Double Battery Life

By far the most outstanding characteristic is the maximum power consumption of 275 mW and 9 mW in sleep mode, which represents a power conservation of 50% compared with a 14.4 kbps modem and 75% compared with a 33.6 kbps modem. In high-speed communications tests with a hand-held personal computer, a continuous battery service life of maximum 5-8 hrs was confirmed.

The company marketed a product for personal digital assistants (PDAs) in July this year which introduces the basic software (Windows CE), and which is attracting consumer attention. Carrying around PDAs featuring long battery service lives is certain to be welcomed by salesmen.

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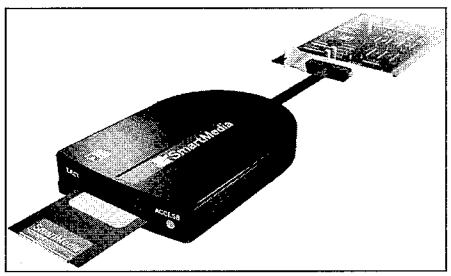
97-12-004-04
High-Speed Smart Media Reader

Hagiwara Sys-Com Co., Ltd. is the first domestic manufacturer to market a newly developed SmartMedia Reader / Writer for desktop personal computers. This SmartMedia Reader / Writer connects to the computer expansion port and allows the data stored on the SmartMedia to be transferred directly to a desktop computer for modification or update.

SmartMedia is an ultra compact storage media in a 4 cm × 4 cm × 0.8 mm package with a capacity of up to 8Mbyte. This media has been adopted by many digital cameras and PDA (Personal Digital Assistants) manufacturers as the storage media of choice because of its size. When data transferring from the digital cameras or PDA to a desktop computer for modification or update is necessary, it is incovenient to use a special-purpose cable to connect the devices together. SmartMedia Reader / Writer will handle this task with ease. Simply install the SmartMedia Reader / Writer into a computer's expansion slot and the SmartMedia can then be used as a floppy diskette. The date transfer rate for the SmartMedia Reader / Writer is twelve times faster comparing to the traditional serial transfer method.



Smart Media Reader

The SmartMedia Reader / Writer comes in three versions (bay type and external type) and is compatible with computer systems that have an ISA bus and running Windows95. The SmartMedia Reader / Writer is marketed at a domestic price of 9,800 yen.

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Process & Production Engineering

97-12-005-01

Technology for Extra-Thin Planar and Curved Machining of Crystal Oscillators

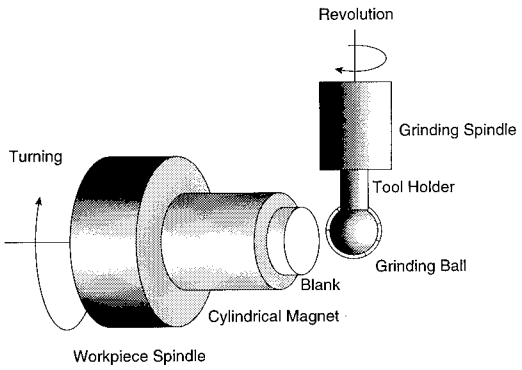
Nagaura Lab. and Industrial Technology Center of Okayama Prefecture have jointly established a technology for the extra-thin machining of the plane and curved surfaces of crystal oscillators. The crystal is fitted on a cylindrical magnet mounted on an ultra-precision lathe workpiece spindle, and the crystal is ground by a grinding spindle, with a tip fitted with a grinding ball, at right angles to the crystal.

Conventional types of duplex lapping machines cannot machine down to a thickness of less than 27 μm, so only plane machining has to be performed. The higher the oscillations generated by crystal oscillators, which are the sources of oscillation of communications frequencies, the higher will be the performance of information processing and transmission communications equipment.

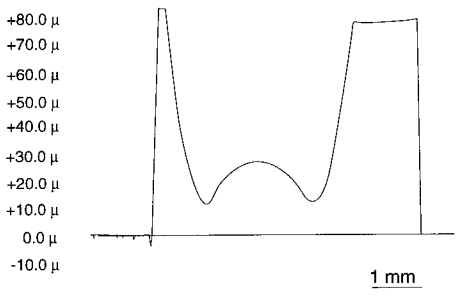
With the new machining technology, the crystal plate is fitted on a cylindrical magnet fitted on the workpiece spindle of an ultra-precision lathe as shown in the accompanying diagram, and a tool holder with sphere-mounting platform is fitted at the tip of the grinding spindle. When machining by bringing the grinding spindle close to the cylindrical magnet, the steel spheres (of a ball magnet electrodeposited with diamond grains) are attracted and held in position on the tool holder by magnetic induction. The grinding ball is held in its position by magnetic force, so it can be changed with ease whenever necessary. In addition, highly accurate steel spheres are used, which eliminate the need for whetstone truing that had been necessary at whetstone changing, so operations can be accomplished rapidly from roughing to finishing. Also, the grinding ball is moved by a numerically controlled (NC) system, so planar and curved surfaces can be machined flexibly.

By applying this new technology, machining to a thickness of 9 μm was accomplished successfully not only of mesa type crystal oscillators but also plano-convex type crystal oscillators in which the retainer part and grooves are formed in a unit form. In addition, a reactance frequency characteristic not accompanied by any spurious resonance was obtained successfully with such an extra-thin plano-convex type crystal oscillator. Examples of the crystal oscillator shape and reactance frequency characteristics are shown in Figs. 2 and 3.

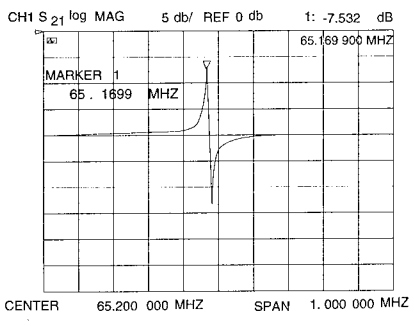
This technology can be applied to the development of high-resolution radar systems, alternative guidedog systems, production automation techniques and high-performance traffic systems.



Schematic diagram of developed machining method



Profile curve of machined quartz oscillator



Reactance freqency characteristic

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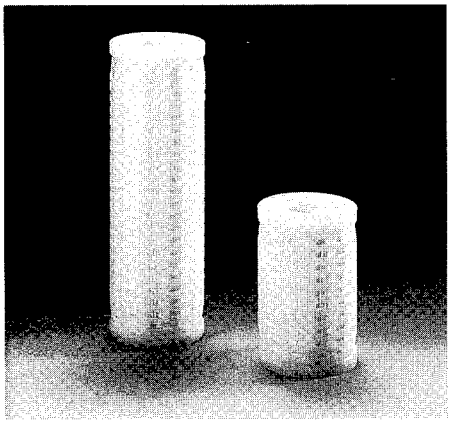
97-12-005-02

Filter Made of Fluororesin for Filtration of Liquid Chemicals

Kurabo Industries, Ltd. has started marketing a filter called Kranfil R for the filtration of liquid drugs, which is made of fluororesin and is hydrophilic to enable precision filtration. The hydrophobic fluororesin is made hydrophilic by excimer laser irradiation to fully utilize the filter chemical resistance, which eliminates the defects associated with the type of filter coated with the conventional type of boundary surface active agent.

The hydrophobic character of the fluororesin is converted into hydrophilicity when an excimer laser beam is irradiated on the fluororesin, during which oxygen in the atmosphere is impregnated on the resin surface. The laser beam severs the molecular bonds of substances, frees

atoms and promotes the bonding of these atoms with other atoms and molecules. Utilizing this hydrophilic PTFE resin membrane enables the filter to be used as a hydrophilic filter consisting entirely of fluororesin. Therefore, the defects associated with conventional types of hydrophilic filters are eliminated, such as the effusion of impurities and unsuitability for use at high temperatures.



Kranfil R

Detergents such as hydrofluoric acid, hydrochloric acid, sulfuric acid and hydrogen peroxide are used in the process of manufacturing semiconductors, and fluororesin filtration materials are used for precision filtration. In these cases, the membranes are frequently clogged with air bubbles to obstruct smooth filtration of the chemicals, so the resin surface is normally coated with a surface active agent. However, previously, the boundary surface active agents were exfoliated by the powerful acids to increase the hazard of foreign substance mixing in the chemicals.

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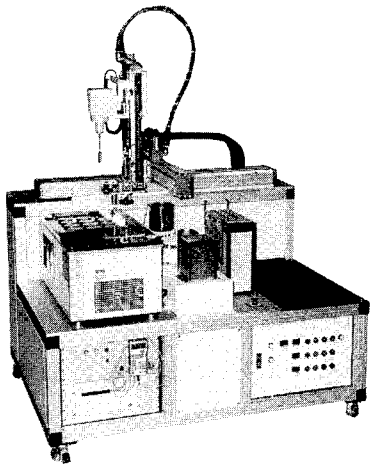
97-12-005-03

System for Automatic Measurement of Viscosity of Multiple Samples

Toki Sangyo Co., Ltd. has developed the world's first Automatic Multi-Sample Viscosity Measurement System. Multiple beakers containing sample liquids are set into the system, data relating to the samples of each beaker are input into a personal computer, and measurements are made of the number of revolutions of the viscosity gauge and the used rotor, and the time of measurement, or the conditions of measurement of each sample liquid, by which the viscosities of all samples inside the beakers are measured automatically.

The system consists of a thermostatic oven to maintain the filled sample liquid beakers at a constant temperature, a rotor washing system to remove the sample liquids adhering on the rotor subsequent to measurements, a rotor magazine to accommodate multiple types of rotors, a loading/unloading system to manipulate the rotors with respect to viscosity detection heads, a three-dimensional robot system, and a table that arranges and fixes these various system members firmly into position.

As the elements of the measuring unit, there are a viscosity detection head for measurements and a controller to transmit and receive measurement signals to the viscosity detection head. Further, as an electronic control element, there is a personal computer for judging the specimen liquid's measurement conditions, measured data processing, overall system control and system operational state control. All these devices combine to comprise an integrated system.



Automatic multi-sample viscosity measurement system

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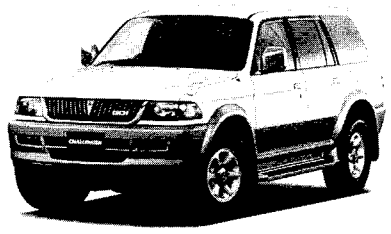
Construction & Transportation

97-12-006-01

Fuel Consumption Reduced by 30% by GDI Engine

Mitsubishi Motors Corp. has redesigned its Challenger series of vehicles. The company's V6 3.5-liter GDI engine is used for powering some models of its new Challenger series. Other features of these cars include electronic management of diesel engine models, improved equipment specifications, a new look and a trimmed interior.

The Challenger series vehicles are powered by Mitsubishi's revolutionary GDI engine, a new benchmark for environment-friendly power units, by which amazingly low fuel consumption is realized, carbon dioxide emission decreased considerably, and the power increased substantially over its port-injection predecessors. Reflecting the sport utility nature of the Challenger, the GDI engine is tuned to deliver greater low-medium range torque, achieves a 30 percent reduction of fuel consumption, a 10% increase of power output in the normal working speed range (600-2,500 rpm), and reduces the emission of carbon dioxide, the cause of global warming, by 30%.



Challenger GDI-XQ

Mitsubishi's 2.8-liter intercooler/turbocharged diesel engine is quite popular due to its clean combustion, high power output, excellent driveability and fast response across the entire speed range. With the new Challenger series vehicles, the introduction

of electronic management realizes the highest levels of power and torque, as well as clean combustion.

The electronically controlled injection system employs data supplied by sensors which monitor the water temperature, throttle opening and boost pressure, to optimize the injection rate and timing. The increased turbocharger boost pressure and the optimization of valve timing enable significant improvements in dynamic performance and driveability. The vehicle appearance is improved substantially by the plated front grill, while the introduction of aeroparts accents the sporty image.

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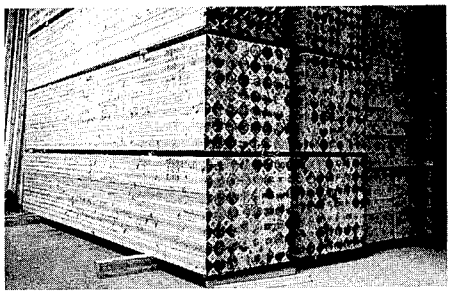
97-12-006-02
Technique to Process Immature Trees into Large Rectilinear Timber

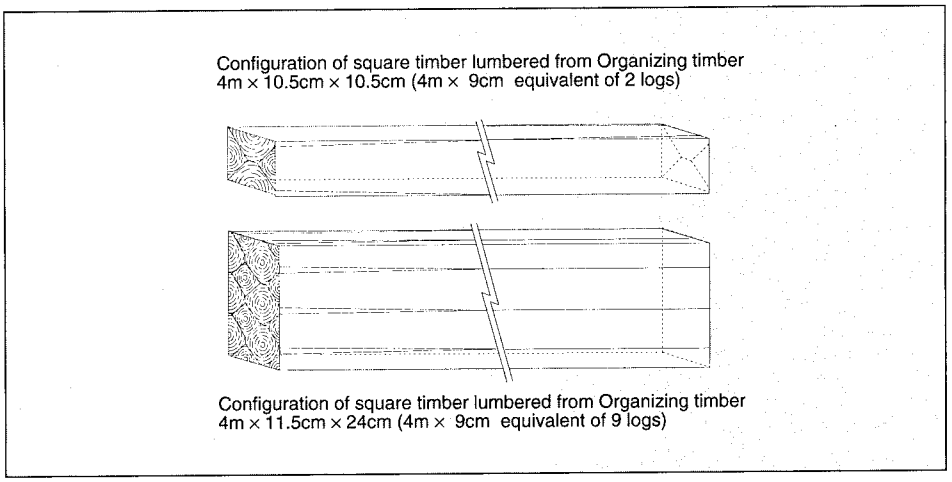
Kyokushin Co., Ltd. has developed a technique that utilizes the immature trees cut down in forest thinning-out operations for processing into rectilinear timbers with a maximum length of 4 m and about 72 cm on each side. Thinning-out trees are generally small and therefore have low added value, and have been used previously only as the supports of street trees and as the scaffold members at construction sites.

The processed square timber strength, when made of cedar, is 1.5 times that of cedar timber, and almost the same or stronger than composite cedar timber. The technique is applicable to hinoki (Japanese cypress) and pine, and moreover there is no special need for approval in conformance with the Construction Standard Law, it can be handled as ordinary timber.

The timber is manufactured by first cutting and neatly arranging both ends of the thinning-out timber, then shaving the part from the central part to the base part in an octagon shape, and the tip part in square shape. The tips and base parts of these members are aligned alternately, sprayed with adhesive, then pressed into a solid square timber. These square timbers must have the same size, so a technique was developed to select thinning-out timbers of about the same size automatically. The operations of outside part shaving, timber inversion, application of adhesive and pressing are all accomplished automatically. The adhesive is a urethane-based adhesive, so there is no health hazard as when using volatile organic compound adhesives. The square timber is marketed under the brand name of Organizing Timber, and various types of applications are presently being studied.



Finished block product



Organizing timber ezsample

The new technique achieves a high yield rate since the thinning-out timber is shaved into a fine taper at its tip part and into a large taper at the base part. Further, the section from the center of the timber to the base part is shaved in parallel with square shape. The sectional area at the square timber central part, multiplied by the length, gives the product volume.

The square timber is produced by labor conservation systems, so manual labor consists only of arranging the base parts of the thinning-out timber in one direction, then feeding them into the system with a forklift truck. After this, the timber central size is detected in units of 10 mm, the timber processed into the prescribed timber size, and these timbers stacked separately by sizes. The processing capacity is 130-150 logs/hr. The timber processing uses a cutter, not a saw, that finishes the timber eight face process by one step. Other than the product, only cutting chips are generated, so cleanup is accomplished with ease.

The machined timber of the same lengths and sizes are bonded together tip-to-base alternately, and compressed into a block with thickness of 10 kg/cm^3, so a large square timber of about 65 cm is produced. This is equivalent to a square timber produced from a log with a diameter of 92 cm.

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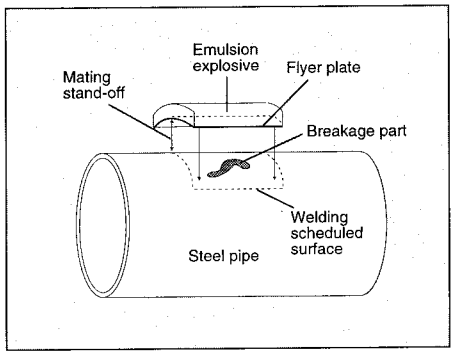
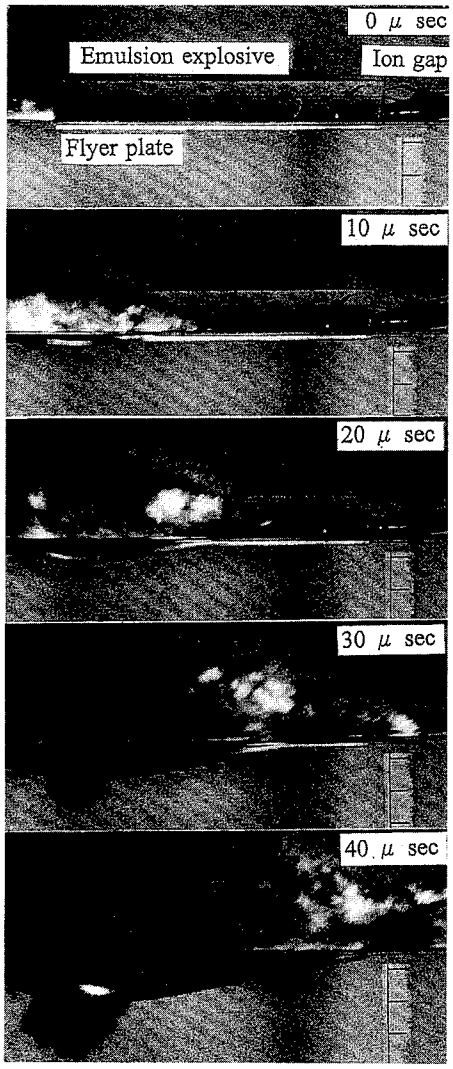
97-12-006-03
Steel Pipe Repair Technique Based on Explosive Welding Method

Y. Ogata of the National Institute for Resources and Environment has established an emergency technique to repair steel pipes by explosive welding using emulsion explosives. The new technique is anticipated to be applicable in the emergency repair of energy lifelines damaged



Concept chart of repairing technique by explosive welding method



Flyer process of flyer plate

by natural disasters, and for utilization in outer space and in deep seas.

With the explosive welding method, the energy of an explosive is utilized to press and join flyer plate onto base materials, and entire plates can be press-engaged over the entire surfaces of the base materials. The technique is being applied to the synthesis of cladding materials. The newly developed technique eliminates the need for a hydraulic press system as well as its power, and permits press-engagement to be accomplished with a simple mechanism. It was established for repairing damaged steel pipes in emergencies, when adequate mechanical facilities and power units are unavailable as when some disaster occurs.

When press-engaging the metal plates firmly onto the damaged pipes, it will be necessary to suppress the steel pipe deformation to a minimum, so the research team studied the optimum conditions regarding the quantity of explosive to be used, the distance between the metal plate and steel pipe, and the weight of the steel plate. As a result, it was discovered that the distance must be over 2 mm to secure firm welding, also that the metal plate weight and quantity of explosive would increase the steel pipe deformation when used excessively, but that the distance factor is not a big deformation factor.

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Energy & Resources

97-12-007-01

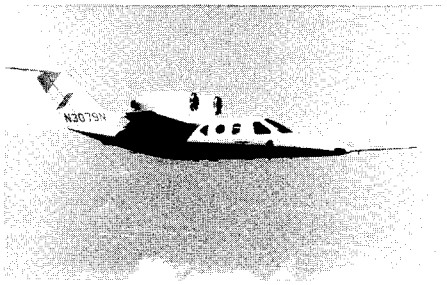
Experimental Jet Plane and Turbofan Engines for Small Aircraft

As part of a research program toward the development of future technologies, Honda Motor has developed a 6-passenger experimental jet airplane called MHO2 and simultaneously unveiled two new turbofan engines for small aircraft. There are no planes for commercialization of any of them at this stage. The MHO2 features a unique, forward bent high wing design (12 degree forward angle- 1/4 wing chord) and a T-type tail wing. The plane's superior low-speed performance allows for Pt135 operation on 3,000-feet runways.

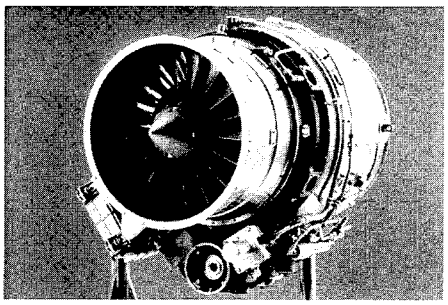
The MHO2 is the first all-composite small business jet, using lightweight carbon fiber reinforced epoxy resins in all structural elements from main and tail cross beams and ribs to fuselage, frame and other outer panels. It is powered by two JT15D-type turbofans made by Pratt & Whitney, Canada Inc. and located at the top of the main wing roots.

Developed as a research engine, work on the HFX-01 started in 1991, with the first ground tests following in Japan in 1993. From 1995 to mid-1996 over 70 hours of tests at high altitude were performed in California. This simple design engine has a take-off thrust of 820 kgf (1,800 lbf) with a low take-off fuel consumption of 0.45 kg/hr/kgf.

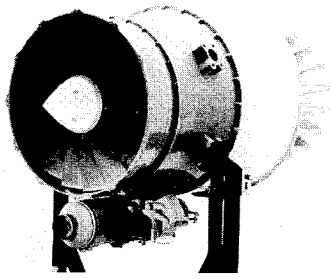
The HFX20 is a prototype engine still at the development stage. Reduced fuel consumption and noise levels together with improved serviceability are the main objectives. Development work continues toward a take-off thrust of 1,000 kgf (2,200 lbf) and a fuel consumption of 0.44 kg/hr/kgf. The building of a prototype and testing on the ground are required before the start of actual test flights within the next two to three years.



MHO2



HFX-01



HFX-20

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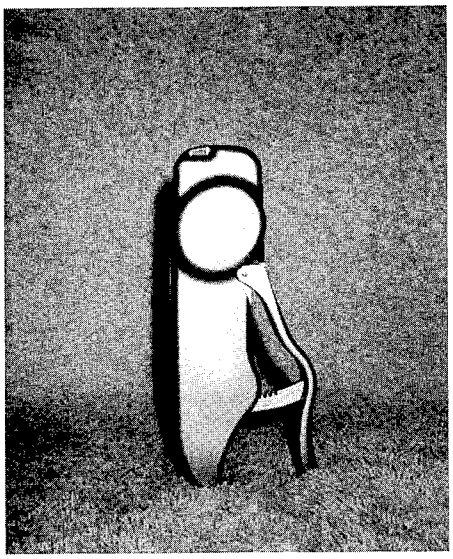
97-12-007-02
Compact Hand-Operated Generator for Charging Diverse Equipment

Nissho Engineering Co., Ltd. has developed a compact hand-operated generator Aladdin Power for charging portable telephones, and plans another version for charging flashlights and personal computers, so marketing a series of generators for energy conservation and emergency use.

Aladdin Power is light (about 100 g) and compact, and can be held in the palm of the hands. The rotor is an outer rotor type in which the magnet part is revolved on the outer side of the coil. Charging is accomplished with ease simply by interlinking a special-purpose cord to the generator and the portable telephone, then working the generator lightly by fingertip action. The generator is marketed at a domestic price of ¥9,800.

The generator output power is 1-1.5 W when operated continuously at a rate of 60-90 cycles/min. Charging is possible in the same way as conventional types of charging devices simply by fitting a special-purpose cord between the generator and the portable telephone unit or other target equipment. It is also usable for charging radios and video cameras by using a special-purpose cord, so is quite convenient for use in work or pleasure when the battery runs out or in cases of emergencies when the power is interrupted.



Aladdin Power

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Environment

97-12-008-01
Bioremediation by Wood-Rotting Fungus

Prof. S. Tachibana and his research team of the Faculty of Agriculture, Ehime University, have discovered a fungus that efficiently decomposes dioxin that is a harmful substance generated through refuse incineration and which is a cause of cancer and physical deformation. The fungus is a wood-rotting fungus belonging to the mushroom family, and experiments have corroborated that the fungus can decompose high concentrations of dioxin ley nearly 90%. The research team plans to develop a fungus having better bioremediation effect through cell fusion for commercialization as a high-performance dioxin treatment agent.

In experiments, a fungus capable of dye decolorization was screened by using Remazol brilliant blue R, a kind of dye, as an indicator. In secondary screening, a fungus having a higher activity of cumulative Lip (lignin peroxidase) was selected. By using this method, three fungi named V1, V2 and 563 with higher degradation capability of 2,7- dichlorodibenzo-p-dioxin (2,7-DCDD) were obtained through screening from the natural world.

The wood-rotting fungi was cultured for 15 days by addition of 2,7-DCDD into the culture medium. The concentration of 2,7-DCDD was 63 ppm, a high value that is over a million times compared with pollutants extracted from the ashes of refuse incineration plants. Using the newly discovered fungi enables decomposition of 85% of dioxin, and including a small volume of dioxin incorporated into fungus body, the decomposition ratio was as high as 90%.

At present, experiments are being conducted indoors, and for safety, are using dioxin of low toxicity from among the 75 types of known dioxin. However, the research team considers that the fungus can treat highly toxic types of dioxin at a high efficiency. The future plan is not only to form fungi having excellent bioremediation effects through cell fusion, but also to find fungi achieving greater decomposition of the dioxin by screening from the natural world.

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97-12-008-02
System for Recycling Waste Foamed Styrol

Naito Sanshi Co., Ltd. has developed a system that melts waste foamed styrol with a solvent, separates the solvent and melted styrol, pelletizes the styrol and completely regenerates and recycles the recovered styrol for reuse in molding. The system has a simplified, compact design enabling the melting apparatus to be installed with ease at the site of waste foamed styrol generation, which eliminates the cumbersome work of transporting the waste styrol to the treatment site.

The system has a size comparable to that of a vending dispensing machine, so its can be installed with ease at a market or supermarket that is a major source of waste styrol generation, and when melting is completed, the treatment tank can be removed for use in the subsequent process of impurity removal. The domestic selling price has been reduced to ¥700,000-800,000, depending on the specifications.

Waste foamed styrol is normally treated by the methods of incineration, ground burial, hot melting or solvent melting, each with its respective advantages and disad-

vantages, but due to the recent social clamor for the reduction of dioxin emissions, the incineration method is impractical.

The company developed a unique simplified system using solvent for melting waste foamed styrol and applied for a patent. An existing system for removing impurities, a solvent tank, a styrol separation system and a system for regenerating the resin in pellet form, complete the integrated recycling system.

The simplified melting system has a melting capacity of about 30 kg in foamed styrol weight ratio, in a form similar to that of a vending machine for soft drinks. It has six 10-liter containers and an 80-liter melting tank, and when the melting liquid attains a fixed density, it is filled into the containers automatically while adding the same volume of solvent. Cassette storage tank conveyance allows the recovery of the filled containers and solvent filling by the same method as for the conventional type of soft drink vending machine. Subsequently, the solvent is stored into a large tank automatically from the conveyed filling container, the container inside is washed and the container reset into the simplified melting system. A continuous high-performance filtration system uses a screen of 5-100 μm mesh for continuous filtration to remove impurities and to obtain a solution that can be regenerated into near-virgin resin.

The separation system uses fixed levels of heat and pressure to utilize boiling point differences to separate resin, solvent and water. The separated solvent is filled into a container, then packed into the simplified melting system. A resin mixing system is used to process the separated resin into regenerated pellets by optional coloring. Regenerated pellets are cut appropriately and stored in the catcher tank. The pellets are filled automatically from the catcher tank into packages with a package filling machine. Various kinds of products can be manufactured with an injection molding machine or a blow molding machine and by using optional colored pellets.

The melting system that is central to this recycling system uses a chlorocarbon-based solvent. Unnecessary evaporation as well as temperature rise at time of reliquefaction are prevented by using a stabilizer or mixing a vegetable extract as an auxiliary liquid. Tests have confirmed that the solvent liquefaction and recovery rate is as high as 97.5%. There is no hazard of system inflammation, melting is performed at room temperature and instantaneously, and waste foamed styrol equivalent to two 4-ton truckloads can be melted within 10 minutes.

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97-12-008-03

In-Situ pH Sensor Measures Seawater Hydrogen Ion Concentration in Deep Sea Very Accurately

The Central Research Institute of Electric Power Industry and the Japan Marine Science and Technology Center, by using an ion sensitive field effect transistor (ISFET) as the pH electrode, have developed an in-situ type pH sensor that can measure seawater hydrogen ion concentration (pH) at a high accuracy that is 5-100 times that of conventional types sensors. Measurements are possible from sea surface to more than 4,000 m deep, and these measurements will clarify how much the sea is uptaking carbon dioxide from the atmosphere.

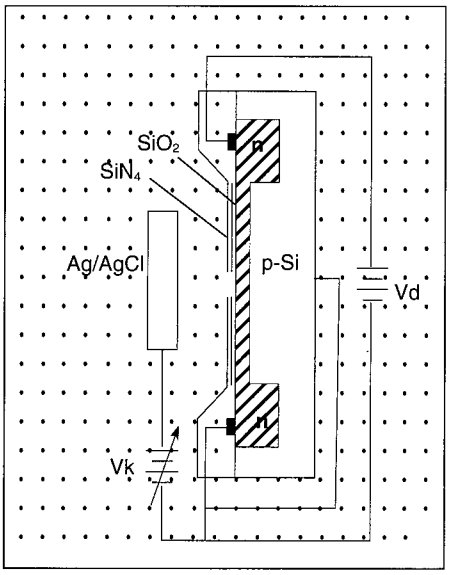
The electrode incorporates a thermistor that enables temperature compensation of the pH value in-situ. The reference electrode is a pressure compensation type electrode that is employed in the field of nuclear power technology, and a porous ceramic material is used in the liquid junction unit.

Today, the final uptake of about one-half of the CO_2 generated by fossil fuels throughout the world is unknown, and there is a difference of about 1 billion tons (carbon equivalent) between the estimated amount deriving from sea measurements and the amount of CO_2 actually generated. Therefore, there is an urgent need to accurately measure the oceanic CO_2 uptake and to elucidate the mechanism of the oceanic CO_2 system.

This new pH sensor uses the ISFET as its pH electrode that was developed for use in the sector of medical treatment. This transistor consists of p-type silicon and its surface is coated with thin films of silicon oxide and silicon nitride. A gate voltage is impressed against the reference electrode. Changing the gate voltage changes the carrier density inside the channels of the semiconductor layers (in the domain where carriers are induced in the semiconductor layers in the proximity of the insulator and the semiconductor boundary surface).

A voltage is impressed between the source and drain, and the current flow will be larger with a higher carrier density (Fig.). Therefore, if the thin insulating film on the ISFET gate is in an aqueous medium, a boundary surface potential will be generated in conformance with the ion activity in the solution, by which the current value between the source and drain will be determined. In this case, silicon nitride is used as the ion sensing film, so hydrogen ions will be sensed to permit pH measurements.

The pH sensor accuracy is as high as 0.01-0.005 pH and its response also very fast. Since it is a solid sensor, it is highly resistant to pressures and impacts. Measurements are possible even to great oceanic depths, and it is also usable as a long-term monitor for measuring pH in deepsea most accurately.



Basic principle of ISFET

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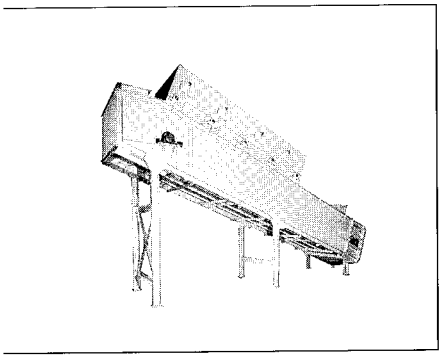
System to Tear and Recycle Sorted, Collected Waste Vinyl Bags

Osaka Magnet Roll Co., Ltd. has started marketing a system called Omrs Bag Tearing Machine that tears sorted, collected waste vinyl bags for recycling as useful resources. It uses a pressure plate that applies the principle of the lever, by which the bag tearing probability is as high as over 99%. The machine is sold at a domestic price of ¥9 million.

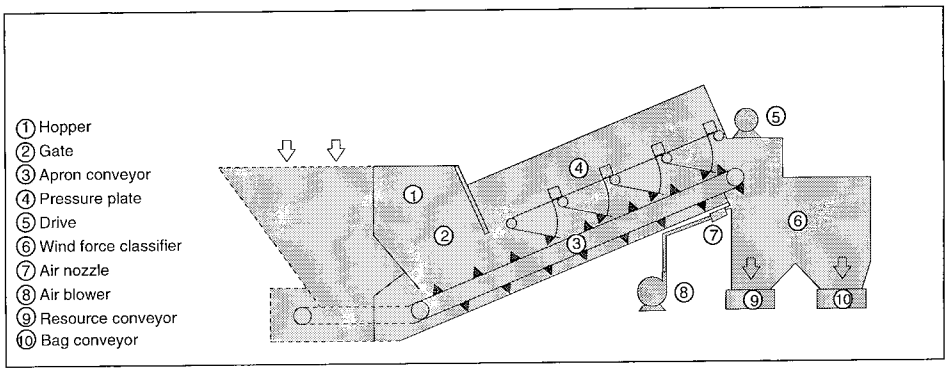
The machine consists of an apron conveyor fitted with numerous teeth and a pressure plate that presses down the vinyl bags. Numerous teeth are provided on the underside of the pressure plate, and the vinyl bags are torn with both layers of teeth. Multiple iron plates serving as weights are laid on the pressure plate with the number increased or decreased to adjust the pressure.



Omrs Bag Tearing Machine

The pressure plate downward force is designed to increase near the apron, matched to the conditions of use, to enable the pressure plate force to be increased when working with large foreign substances. The force acts exactly opposite compared with the spring force and enables efficient tearing and extrusion of foreign substances. The teeth provided on the apron and the pressure plate are not sharp but dull since the purpose is to tear the waste vinyl bags.

The bags are torn with the upper and lower units of teeth, so both large and small bags are torn by action of four rows or a total of 16 pressure plates. After tearing, the fragments are separated with an air separator into can and bottle fragments as well into vinyl bag fragments for recycling as useful resources. The machine has a treatment capacity or 4.5-9 t, or 25-45 m^3/hr. The machine is a mechanized version of the conventional manual tearing method using sickles and was developed for use in the preliminary treatment of sorting useful refuse.



Structure

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Biotechnology & Medical Science

97-12-009-02CCMC

CAD/CAM System for Dental Application

Advance Co., Ltd. has developed and started marketing a computer-aided design and computer-aided manufacturing (CAD/CAM) system called Dental Cadim for dental applications that mills the teeth crowns very accurately. It is a compact system that performs measurements and grinding operations automatically by computerized control, and is sold at a domestic price of ¥5,900,000.

Dental Cadim is a personal CAD/CAM system that performs the three major tasks of measuring, modeling and manufacturing, and enables dental technicians to fully display their own individualistic creativeness. The system consists of a mechanism unit, a spindle system, a measurement unit, a controller unit and a personal computer. The actual moving area is a domain that is 150 mm in the X-direction and 100 mm in the Y- and Z-directions, within which there are the measurement probe (stylus), jigs, holding tools, cold water system, grinding collet and grinding reference point square pole measuring reference point.

Grinding is accomplished with a high-torque spindle motor revolving at a high speed in conformance with a personal computer-controlled operating system (OS) compatible with Windows 95. The contact measurement system is adopted for making measurements in the dental prosthesis, so very accurate and rapid measurements are possible. The accuracy adaption to crowns is as high as 20 μm, which is equivalent to the coating thickness of dental adhesive cement.

The system is usable for grinding not only dental metals but also ceramics as well as pure titanium that cannot be worked by conventional casting techniques. The shape of the device is so designed that it enables inlays, unlays, cores and crowns of all kinds of shapes to be machined flexibly and accurately, also the milling of multi-linked crowns and bridges. In addition, metal frames and false teeth plates can be machined flexibly in conformance with specific needs, and related data can be preserved.

Another distinct advantage is that all operations from teeth pattern taking to the fitting of dental crowns can be completed within the day.

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